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Biological and Ecological Studies of the Spruce Budworm

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Ecological and biological studies of the spruce budworm, *Archips fumiferana* (Clem.), were conducted in northern New York State in 1946 and 1947 to obtain information of use in developing forest practices that would reduce the hazardous budworm condition in spruce-fir forests. This paper is a preliminary report of studies on the life history, feeding, development, oviposition, and survival of the budworm, as well as the effect of budworm feeding on the trees. When the experiments were started it was not known how serious the spruce budworm outbreak might become. Many of the studies were on controlled experiments with a limited number of specimens, since the authors desired to get as much detailed information as possible. These studies were therefore different from the over-all gross studies of mass effects of heavy populations made by Swaine & Craighead (1924) in Canada in 1920–23[1], however, many of the results are remarkably similar.

Older balsams may produce an abundance of male flowers. The part these staminate flowers play in the development of the budworm population has been the object of considerable study in this country and in Canada. It has been reported that trees having an abundance of male, or staminate, flowers are more attractive to the moths for oviposition than are those having foliage only. Also, it has been reported that the budworm larvae developing on trees with staminate flowers may produce females with higher egg-laying potentials and thus serve as "brood trees," on which the population builds up rapidly. The studies here reported have shown that the budworm larvae have only a short feeding period on the pollen in the field. During the 1946 season all balsam pollen was shed from the flowers in the field before May 28. On that date only a few larvae in the field had entered the fourth instar. Checks made on June 20 of larvae feeding on balsam trees that had had staminate flowers revealed that most larvae were in the sixth instar. No pupae were found. Balsam trees that had had no pollen-bearing flowers were checked on the same date and larvae on them were also found to be in the sixth instar. Apparently the small amount of feeding on pollen did not greatly speed up development of the budworm in the field in 1946.

In 1947 flowering and nonflowering balsam firs were selected for a study of the variations in larval development. Periodic examinations showed that the larvae on the trees having staminate flowers were slightly ahead in development of larvae feeding on foliage only. This is what might be expected, for at the time the larvae were leaving the mined needles in May most of the vegetative buds were still very tight and hard, but the staminate buds were swelling and were available for food. Thus the larvae feeding on them obtained a slight advantage and maintained this lead over those feeding only on the vegetative buds.

In the laboratory the larvae were allowed to feed on balsam pollen for a longer period because the pollen in the rearing boxes remained moist and suitable for food. This pollen feeding caused the larvae to mature considerably earlier than those feeding on balsam needles only. Oviposition studies showed that 10 females from larvae having access to pollen deposited an average of 171 eggs each, whereas 10 females from larvae not having access to pollen deposited 175 eggs each. Dissections of gravid females were made and no evidence could be found that females from larvae having access to pol-

len had higher egg potentials than those not having access to pollen.

A sample of 900 pupae that developed from larvae supplied with balsam staminate flowers for food showed a sex ratio of 0.48, whereas a sample of 2000 pupae from larvae that fed exclusively on balsam foliage showed a sex ratio of 0.53.

It should be pointed out that in 1945 and 1946, when relatively few trees produced staminate flowers, there was a great increase in the budworm population in the Adirondacks. In 1947, when there was an abundant production of staminate flowers on balsam fir and spruce—apparently ideal food for maintaining or increasing the population—there was a sharp reduction in the budworm population.

The decrease in the budworm population is probably due to a combination of many factors, such as forest type, which in turn affects the parasitic insects and fungi, and also predaceous insects, spiders, and birds. The forest type may be especially important. The Adirondack area is on the southern fringe of the spruce-fir region and the softwoods there are in small areas amongst hardwoods, not in large contiguous areas like those found farther north, where the budworm takes an enormous toll of the spruce and fir trees. While the larvae are small many are wind-borne and may reach hardwood trees unsuitable for food, whereas in large solid blocks of spruce and fir suitable host trees would be available regardless of direction of movement. The same may be true of moth flights or movements.

A study of the effect of feeding on different species of trees and on different types of foliage was deemed essential to a better understanding of budworm behavior and survival. In 1947 two series of individual rearings were initiated on balsam-fir needles, on red, black, and white spruce, and on balsam pollen. In one series the 1946 growth with 1947 buds was used, whereas in the second series only the 1945 growth was used. Second-instar larvae that had hibernated on trees in the field were collected in May and transferred to individual vials for rearing on the various types of foliage.

In the first series survival was 100 per cent on balsam and on black spruce twigs taken from young vigorous trees, 71 per cent on white spruce, 68 per cent on red spruce, and 96 per cent on balsam with pollen available. In general, survival was high on foliage of all species used, whenever the larvae had access to 1946 foliage plus the 1947 buds. A number of larvae went through more than six instars. On black and red spruce all the larvae went through at least seven instars, whereas on red spruce several of the larvae actually passed through eight instars before pupation. The pupae from larvae on red spruce, which passed through eight instars, were no larger than those that developed from larvae that had gone through only six instars on balsam.

In the second series, where only 1945 foliage was available for food, the larvae that fed on balsam showed the same high survival as in the first series, thus demonstrating that the budworm can develop on old balsam foliage as well as on current foliage and on that one season old. Mortality was high among larvae on red, black, and white spruce and budworms that did survive to reach the adult stage were usually smaller. Their egg potentials were found to be approximately 25 per cent less than in those reared on balsam.

A study was conducted to ascertain whether the budworm moths showed a host preference for oviposition. Two cages containing branches of balsam fir, and of red, white, and black spruce were set up. Several hundred male and female budworm adults were liberated in each cage. At the end of each 24-hour period the egg masses were removed and counted and the branches were rearranged.

The results clearly indicated that in cages white spruce had first preference for oviposition, having the largest number of eggs and egg masses, regardless of where the foliage was placed in the cage. Approximately 15,000 eggs were deposited, 40 per cent of which were on white spruce. Egg deposition on balsam fir and on red and black spruce was 20, 22, and 18 per cent, respectively, indicating little difference between these species. Observations indicated that certain foliage characteristics, such as length and arrangement of the needles, affected the selection of an oviposition site.

The staminate flower bracts on balsam fir have been reported to be the preferred location for hibernation. Three hundred first-instar larvae were placed on a balsam branch late in July 1946 to determine

whether they preferred staminate flower bracts for hibernation. This branch had produced a profusion of staminate flowers in 1944 and 1946. In March 1947, 255 larvae were recovered, 47 per cent having hibernated in the annular scales and 53 per cent in the staminate bracts. This indicated little or no preference for staminate bracts as a place for hibernation. All the larvae were found within 18 inches of the point of release, showing that if desirable places are available the larvae do not wander far before hibernating.

A young balsam fir on which 1100 first-instar larvae had been placed early in August 1946 was examined in February 1947. Of the larvae recovered, 83 per cent were hibernating among the scales at the base of the 1946 growth, 6.5 per cent in the scales at the base of the 1945 growth, and 10.5 per cent in the annular scales formed prior to 1945. Apparently most of the larvae hibernate out near the tips of the branches. As soon as a larva finds a desirable location, whether it be an annular scale or a staminate bract, it spins its hibernaculum.

The author attempted to determine some of the causes of mortality of the hibernating spruce budworm larvae. One study consisted of placing 1100 first-instar larvae on a 6-foot balsam fir tree during the period July 30 to August 12. It was common to see spiders seize larvae that had just spun down from one branch to another, but no exact count of mortality from this cause was made.

In February 1947 the tree was minutely examined twig by twig with a binocular microscope and 733 hibernacula were found, of which 583 contained living larvae, 43 contained desiccated larvae, 36 larvae attacked by fungus, 15 remains of second-instar larvae, and 56 were empty.

In January 1948 an examination of 591 hibernating larvae revealed a mortality of 57 per cent. Fifty-two per cent had been attacked by fungi, 4 per cent were desiccated, and 1 per cent were parasitized by a chalcid. In the previous year only 5 per cent of the hibernating larvae were attacked by fungus.

To determine the overwintering survival of the spruce budworm on spruce and fir, in July, 1946, 500 first-instar larvae were placed on a red spruce, 800 on one balsam, and 1000 on another balsam. In the spring of 1947 these trees were examined periodically and counts were made of the various stages present. On May 21, the needle-mining period, there was a survival of from 16 to 25 per cent. Natural control factors further reduced the population during the larval and pupal periods and only 1.8 to 2.8 per cent of the individuals reached the adult stage. Survival on these small trees was even higher than that which occurred generally throughout the Adirondacks, for there was a decided decrease in moth population in 1947, as compared with that of 1946. With a survival of even 2 per cent, there would have been an increase in population.

In 1946 approximately 600 mined needles on balsam fir and black spruce were tagged, to determine the mortality of budworm larvae during the period between the needle-mining and the bud-feeding stage. In 1947, 600 mined needles were again tagged for observation of mortality on balsam fir, black spruce, and red spruce.

It was thought at first that loss may be great during the needle-mining period, owing to the dropping of mined needles with budworm larvae in them. Apparently, the physiology of the mined needles is upset by the mining activities of the larvae, causing the needles to drop prematurely. However, observations showed that most of the budworm larvae leave the mined needles before the needles drop. For example, on May 27, 1946, of 244 mined and tagged balsam fir needles still remaining on the trees, only 9 contained budworm larvae. Collections were made in 1946 and 1947 of fallen mined needles. Examination of fallen needles under balsam fir showed that about 12 per cent contained larvae, under black spruce 7 per cent, and under red spruce 2 per cent.

Many a budworm larva could be traced from the mined needle to a bud by its silken thread, or by the proximity of the mined needle to the bud entered. In 1946, 65 per cent of the larvae in the tagged mined needles on the balsam fir reached the expanding buds, while on black spruce only 8 per cent were traced to the buds. In 1947, 42, 26, and 7 per cent of the larvae reached the buds from marked mined needles on balsam fir, red spruce, and black spruce, respectively.

In 1946 the number of larvae that left the mined needles and could not be ac-

counted for amounted to 30 per cent on balsam fir and 87 per cent on black spruce. In 1947 the larvae that could not be accounted for after leaving the mined needles was 50, 72, and 86 per cent on balsam fir, red spruce, and black spruce, respectively. These unaccounted-for larvae cannot all be considered dead, because it is known that some drop onto lower branches and enter new needles or buds. Small larvae were observed hanging on silken threads and some were caught on a tanglefoot screen about 300 feet from any balsam fir tree. Undoubtedly mortality is high during the period when larvae are seeking expanding buds.

In 1947 the vegetative buds on black spruce and red spruce were very late in opening. The 26 per cent of budworm larvae recorded as being in buds of red spruce on June 4 were all in staminate flower buds. The delay in the swelling of the vegetative buds on red and black spruce caused more than the normal amount of movement by the larvae seeking suitable buds. The larvae on spruce were thus exposed for a longer time to predators than were those on balsam fir.

Spruce stands in northern New York did not show heavy foliage injury during the current infestation; however, in some areas there was considerable injury to the vegetative buds of red and black spruce. Both these species normally produce nearly twice as many accessory or axillary buds along the twigs as are produced on balsam, and because of these additional buds there would appear to be less actual damage by the budworm. As previously pointed out, there is a greater mortality of the budworm larvae on the spruces than on the balsam, owing to the delay in the swelling of the buds. The reason for the extensive bud destruction on the spruce trees is that larvae able to survive until the buds are suitable for feeding consume a greater number of the small spruce buds.

A total of 40 observation plots in 12 areas have been established in the Adirondacks for the study of the biology and ecology of the spruce budworm. Most of these plots are in balsam fir stands, but several are in stands of black and red spruce. These plots vary in stand composition, density of stocking, age, and vigor.

The amount of defoliation on 15 trees in each of 37 plots was estimated in 1945, 1946, and 1947. The estimates in 1946 showed an increase in defoliation over 1945 in 6 plots, no change in 8 plots, and a decrease in 23 plots. Many of the plots showing a decrease in defoliation were on the periphery of the budworm-infested area. In 1947 there was a marked decrease in per cent defoliation in all but two plots. The information obtained to date does not indicate that a stand of any particular age group, vigor class, or site condition was more susceptible to the budworm than any other.

Increment borings were taken in 1946 and 1947 at d.b.h. from representative trees in 35 balsam fir plots in the Adirondacks. Regardless of the age, site condition, or amount of budworm defoliation, the plots show the same general growth pattern for the last 6 years. There was a decrease in growth in 1943 and still further decrease in 1944. In 1945 growth increased on trees in all plots, regardless of the amount of budworm defoliation. This was the first year of severe budworm feeding, and trees on several of the plots had 100 per cent of the current season's foliage eaten. In 1946 and 1947 there was a marked decrease in growth over that of 1945, but trees with very little or no defoliation showed the same trend. In all the plots except one the growth made in 1947 was the least in any of the last 6 years.

The only indication of budworm defoliation affecting the rate of growth of balsam in the Adirondacks was on trees that had had two years of heavy defoliation followed by a third year of medium defoliation. In 1947 these trees showed an appreciable reduction in radial growth at breast height, and a sharp reduction at the tops.

It is believed that this information may be of some help in developing sound forest practices that will help produce spruce-fir forests more resistant or tolerant to budworm injury.

SUMMARY.—Ecological and biological studies on the spruce budworm were conducted in northern New York during 1946 and 1947.

Budworm larvae that fed on trees having staminate flowers were slightly ahead in development of those that fed on trees not having flowers. Female moths from larvae that fed on pollen did not lay any more eggs than did females from larvae that fed on vegetative growth. Feeding on pollen-bearing flowers had no effect on the

sex ratio. In 1947, when there was an abundant production of staminate flowers on balsam fir and spruce, the budworm population was greatly reduced.

Feeding experiments in the laboratory in 1947 on balsam fir, and on red, black, and white spruce showed that survival of budworm larvae was high on all tree species if the larvae had access to 1946 foliage plus the 1947 buds. When only 1945 foliage was available for food, the larval survival was high on balsam-fir but low on red, black, and white spruce. The larvae that survived on 1945 spruce foliage produced moths that were usually smaller and had a lower egg potential.

Studies indicated that white spruce was definitely preferred by the female moths for oviposition over balsam fir and red and black spruce. The characteristics of the foliage appeared to have an effect on selection of a place for oviposition.

The young larvae, in seeking places for hibernation, showed little or no preference for staminate bracts. Most larvae hibernated within a short distance of the egg cluster if a suitable place was found. Examination of hibernating larvae in February 1947 showed 20 per cent mortality by midwinter. From time of hatching in July 1946 until late in May of the following year, when larvae entered the needles, there was a loss of 75 to 84 per cent. This mortality increased to over 97 per cent up to the adult stage. During 1946–47, 5 per cent of the larvae were attacked by fungi during the overwintering period, but the attacks increased to 52 per cent in 1947–48. The loss of budworm larvae from the needle-mining period to the bud-feeding period was very high, especially on black spruce.

Defoliation caused by the spruce budworm was recorded on 37 plots for the years 1945, 1946, and 1947. The 1946 estimates showed an increase in 6 plots, no change in 8 plots, and a decrease in 23 plots, many of the last being on the periphery of the budworm area. In 1947 there was a marked decrease in the per cent defoliation in all but two plots.

Increment borings were taken on trees in several plots, but the only indication of budworm defoliation affecting the rate of growth of balsam fir was in trees heavily defoliated for two successive years followed by a third year of medium defoliation.

LITERATURE CITED

Swaine, J. M., and Craighead, F. C. 1924. Studies on the Spruce Budworm [*Cacoecia fumiferana* Clem.]. Canada Dept. Agr. Bul. 37, N. S. (tech.), part II: 28–57.

TOXAPHENE—A COMMON NAME FOR THE INSECTICIDAL CHEMICAL CHLORINATED CAMPHENE

The word toxaphene has been accepted as a coined common name for the insecticidal chemical referred to as chlorinated camphene having a chlorine content of 67 to 69 per cent. The term toxaphene is to apply to the technical insecticidal chemical produced and meeting the standard prescribed in the foregoing sentence.

Acceptance of the word toxaphene as a coined common name for this insecticidal chemical has been possible through action taken by the Hercules Powder Company to relinquish the trade-mark name *Toxaphene*. The Hercules Powder Company has taken appropriate action to surrender the trade-mark name, and such action has been officially recorded.

The acceptance of the name toxaphene for the coined common name of this chemical has been agreed to through cooperation and consultation with committees, various associations, representatives of interested Governmental agencies and after consultation with industry and representatives of the Trade-Mark Division of the United States Patent Office. Those participating in the acceptance of this common name and concurring in its suitability include CHEMICAL ABSTRACTS of the American Chemical Society; Council on Pharmacy and Chemistry of the American Medical Association; Committee on Insecticide Terminology of the American Association of Economic Entomologists; the National Association of Economic Poisons Control Officials; representatives of the Insecticide Division of the Production and Marketing Administration; the Food and Drug Administration; the Public Health Service; and the Bureau of Entomology and Plant Quarantine.

The Committee on Insecticide Terminology of the American Association of Economic Entomologists reported to the Association at the business session of the annual meeting on December 16, 1948, that the Committee had accepted toxaphene as the coined common name for this insecticidal chemical, conditioned on the final surrendering of the trade-mark name. The Association accepted and welcomed this announcement.

S. A. ROHWER, *Chairman, Interdepartmental Committee on Pest Control*

The Beech Scale and Beech Bark Disease in Acadia National Park[1]

A. E. Brower, *Maine Forest Service, Augusta*

Beech scale is by far the most important insect pest of beech in the Northeast. This imported pest, *Cryptococcus fagi* (Baer.), has been known for a long time in Europe. In 1931 it was discovered in Maine in several towns near Calais and at Liberty, both infestations being of several years standing. Scouting during the next 3 years showed that the infestation extended north and west to Vanceboro, Topsfield, and Whiting; and infestations were found in Waltham, east of Millinocket, several towns about Liberty, and an infested area in York and Eliot. By 1936 most stands in the southeast quarter of Maine were heavily infested. Due to its very destructive attacks on beech stands in Nova Scotia, its rapid spread in Maine was viewed with alarm, and surveys have been made to record its advance across the state. It spread rapidly and less injuriously through the mixed younger beech stands of south central and western Maine, reaching the western and northwestern borders and New Hampshire by 1943. Its spread northward has been slower, the first heavy infestation being recorded from the Portage area in 1948. The beech bark disease was found in one spot north of Ashland in the fall of 1948.

The destruction brought on by beech scale is anomalous. Despite the large percentage of bark it kills on the trunks of trees which it attacks, the claim is made that the scale alone does not kill any trees. Trees heavily attacked by the scale are regularly attacked by the otherwise impotent beech bark disease fungus, *Nectria coccinata* var. *faginata* Lohman, A. J. Watson and Ayers, and this combination has killed or badly damaged a great part of the large beech attacked. Occasionally trees as small as 5 inches in diameter are killed, and even small sprouts may be heavily infested with scale. Figures of the percentage dead give a very misleading picture of the damage done because many of the old trees will live on with but a few small trunk branches remaining alive. Near Princeton in 1946 an old beech ridge gave a count of but approximately 50 per cent dead, but the destruction of the canopy was near 100 per cent and a thick stand of beech sprouts had come up as in a clear-cut area. The destruction of most of the remaining severely damaged beech seems but a matter of time from the heavy infestation of *Fomes fomentarius* which followed. Destruction of the old beech in Acadia National Park has reached 40 per cent in some places, with most of the remainder severely damaged. The beech bark disease has regularly followed heavy scale infestations, being found a few years after the scale.

The beech scale is wingless and parthenogenetic. It spreads in the crawler stage which appears in August and September. Due to the fact that the beech in Acadia National Park on Mount Desert Island is isolated by a water barrier of a few miles or more, in most places, from the nearest beech on the mainland, and still more isolated by low-lying beechless areas of farms and coniferous growth on the northern part of Mount Desert Island and the nearby mainland, it was hoped that the insect would not be able to cross to beech on the Island. The following control work and spraying has been carried out by the National Park Service, the writer acting as a Collaborator of the Bureau of Entomology and Plant Quarantine, U.S.D.A., for Acadia National Park.

Early in 1934 the first few infested trees were found in the Park in one of the central valleys. Since scouting yielded no more infested trees eradication was decided on. The trees were heavily sprayed with kerosene to a height above evident scale, set on fire, and later felled and removed from the woods. In 1935 and 1936 more infested trees were found close by and these were removed from the woods. In 1936 another infestation was discovered more than a mile away in another valley, The Gorge, where about 2 acres of beech were infested. Heavily infested trees were cut and removed. In the spring of 1937 both of these areas and neighboring trees were thoroughly sprayed. Commer-

[1] The author wishes to acknowledge the criticism of Dr. Perley Spaulding, Principal Pathologist, Agricultural Research Administration, in the preparation of this paper.

cial liquid lime sulphur was used at the rate of 5 gallons to 95 gallons of water. In the period 1934 to 1937 many of the important beech stands were examined at varying intervals for the scale, but no thorough examination was made of the beech on Mount Desert Island. During January and February 1938, A. L. Jones and a crew of C.C.C. boys scouted and mapped all of the beech stands on the Island. As was feared, the beech scale was found more or less distributed in the majority of the beech areas. Beech was found on about 1197 acres, with about 1200 of the trees infested. Since then the scale has spread to about all beech trees on the Island.

In the spring of 1938 all known infestations which were accessible to roads were sprayed. Thirty-seven areas were sprayed, as was the beech in an additional 50-foot safety belt around each infestation. About 4000 trees were sprayed. Back pumps were used to reach and spray some of the infested trees too far from a road.

These spraying operations did not eliminate the scale in the areas sprayed. Due to small weak hose, lack of operating pressure, inadequate supervisory force, winds and other factors, the top of the infestation could not always be reached and some trees were missed or incompletely covered. Scale has been found up to 65 feet above the ground. Lime sulphur discolors the trunks and kills all of the moss and lichens, which generally makes unsprayed trees noticeable and facilitates a check on coverage. The higher the pressure the more readily the moss and lichens can be wet thoroughly in order to kill the scales hidden beneath. Inspection of the sprayed areas, with a microscopic check on any suspicious looking patches of scale, showed that complete kill could be secured. Thoroughly wetting the trunks with standard strength liquid lime sulphur 5 gallons to 95 gallons of water, or 20 pounds of dry lime sulphur in 100 gallons of water, will give 100 per cent kill.

In the spring of 1939 the spray program was reconsidered. This led to the abandonment of the plan to spray all of the beech. Four large plots and three smaller ones were selected for preservation. Later the three small areas were abandoned. This revised program was based on the belief that the scale could be controlled by spraying at intervals of a number of years. Apparently, thorough coverage with lime sulphur before the leaves open in the spring will both kill all the scale present and prevent reinfestation during the year. Light infestations have been observed to require 2 to 3 years or more to build up to the danger point, the danger point being that point causing sufficient injury to permit an injurious infection by the beech bark *Nectria* to be established and to develop. Difficulty in securing enough labor made this time interval most important, and as the war came on labor was less available. One area was sprayed in 1939, but during the next 3 years but one more area was sprayed. Examination of the plots in the spring of 1943 showed that the infestation was heavy on plots which had not been sprayed for 5 seasons. One plot was not sprayed until the spring of 1944 after 6 seasons and the infestation became very heavy, and some of the trees were killed. Spraying this plot destroyed the scale and apparently stopped the *Nectria*.

In the early spring of 1943 well-developed infections of the *Nectria* which causes the beech bark disease were discovered in one and near another plot about 4 miles apart, and later in the year this disease was found on a third plot. This disease develops very slightly, if at all, on uninjured bark. Scale injury is a prerequisite for the development of an important infection. Heavy infestation by the scale may be followed by heavy infection by *Nectria*, but never the reverse. On trees where the scale reaches a medium to heavy infestation, this disease often attacks severely, following the scale in a few years. Many square feet of the trunk may be thickly dotted with the dark red fruiting bodies. Nectria fruiting is often strikingly associated with the vertical strips of previous heavy scale infestation. The scale develops a heavy strip infestation running up the northerly side of the trees and this is followed by heavy *Nectria* fruiting on the same area. After the *Nectria* infection kills large areas of bark which encircle the trunk the tree dies. Bark killed by *Nectria* dries, shrinks, and clings tightly to the trunk. Generally the bark on the southerly side, where the scale was lightest or patchy, is irregularly killed by the *Nectria*.

One of the most remarkable things to be seen everywhere is the great tenacity of beech trees. Many trees which seem to be

almost if not completely girdled are evidently able to transfer enough food material through devious slender channels to prevent death, though a considerable portion of the top often dies. The cycle of events is as follows. With some scattered scales to start with, the infestation can build up in 2 to 3 years to the point where dangerous *Nectria* infection may occur. In 3 to 4 years from the start *Nectria* fruiting bodies appear often in large numbers. Then the tree may die or survive more or less severely injured. A large majority survive, but many lose more or less of their tops. On trees which live, first the scale and then the *Nectria* subside to much lower levels of infestation and infection respectively. One to 3 inch trees are often rather heavily attacked by the scale, but not by the *Nectria*. Whether or not they will grow into trees resistant to *Nectria* is a point which must be determined in the future, but apparently injury to the wood and growth is important.

When the first infections of *Nectria* were discovered in the Park in 1943, trees with fruiting bodies were cut, burned, scorched with a gasoline torch, or sprayed with concentrated lime sulphur solution. Most of the diseased trees were removed from the woods. Later discovery of additional infected trees near those removed in other places led to the realization that the disease could not be eradicated or greatly checked with the labor available. The decision was then reached that practical control depends upon keeping the scale infestation low enough to prevent *Nectria* infection, and this became the aim of control work on the plots. Results to date support the conclusion that if the scale is held to a medium or lower infestation the *Nectria* disease will be of small or negligible importance. The disease is evidently dependent for injurious development upon injuries or an abnormal physiological condition produced by the scale in the bark. In this project the term "medium" is applied to the stage when the abundance of the scale reaches the point where a number of patches from the size of a nickel to a quarter are covered with the flocculent whitish covering or when dense vertical lines of scales are present in crevices, with lesser numbers scattered out from these concentrated spots. Nearly always the infestation develops first on the side of the tree least exposed to the sun and there is also a strong tendency for vertical lines of infestation to develop. In August and early September when the young crawler stage is present, medium infestations have 2 to 3 thousand crawlers per square inch of most heavily infested bark. These concentrations will be limited to one side of the tree. Infestations termed "very heavy" have a crawler population of 4000 to 6000 or more crawlers per square inch.

Any natural control which exists is ineffective in holding the beech scale in check. The twice-stabbed lady-beetle, *Chilocoris stigma* (Say) is frequently found in some numbers feeding on the scale, and in areas where the scale exists in low numbers it may be an important check on the scale. No parasites of the scale have been found. Extremely cold winters seem to kill a large percentage of the exposed scales, but the ordinary winter temperatures apparently are not severe enough to prevent rapid multiplication in numbers.

SUMMARY.—Beech scale has spread rapidly in Maine. In some of the old stands beech has been almost completely killed or badly damaged. The scale crossed the water and beech-less fir-spruce barrier to reach beech on Mount Desert Island. There it became distributed widely in 4 to 5 years, despite attempts to eradicate or control it. Thorough spraying with liquid lime sulphur 5 gallons with 95 gallons of water has been found to give 100 per cent kill. Residual action of a spring application apparently prevents reinfestation during the current season. With thorough coverage the spray interval can be 4 to 5 years, depending on the proximity of unsprayed infested beech to the sprayed trees. The beech bark (*Nectria*) disease is dependant on injuries or an abnormal physiological condition produced in the bark by the scale for successful attack and development. Spraying the beeches before the scale infestation reached a point described as medium to heavy soon stopped development of the disease. Surviving trees develop a resistance, apparently in the bark, to attack, and first the scale and later the *Nectria* disease subside to much lower levels. Sprouts and small young trees show greater resistance to the scale and are not attacked by the *Nectria*, but the amount of injury to the wood and growth may be serious.

Biology of *Gnathocerus cornutus*

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Gnathocerus cornutus (Fab), the broad-horned flour beetle, is found nearly everywhere in the United States, according to the available data. This insect is injurious to a number of cereal and animal products In spite of its economic importance only a few papers on its biology have been published; the latest account in 1926. Much of the information is conflicting, which may be due to unfavorable environmental conditions. A series of physical environmental tests were carried out to correlate data on the biology of *G. cornutus*.

EQUIPMENT AND METHOD.—The equipment was simple but gave good control of moisture and temperature. Moisture was measured in terms of saturation deficit. Saturation deficit is the difference between vapor pressure at 100% saturation and actual vapor pressure. This is a better index of rate of evaporation which is less dependent on actual temperature (Buxton, 1931). Saturation deficit was controlled with saturated salt solutions in glass-topped, pint fruit jars. The cages containing the insects were suspended in the jars and these moisture chambers placed in constant temperature chambers. The food used was meat-bone meal plus Haydak's (1936) mixture which consists of yeast, cereal, and milk products.

Since the eggs were very difficult to find in this food, adult beetles were used to start tests in each environment. The adults were exposed in the environments for two weeks, then if oviposition occurred data were obtained on the immature stages.

DESCRIPTION.—The egg has a glistening milky white appearance, measuring approximately 0.44 mm. in width and 0.76 mm. in length. It is adhesive when laid, and becomes coated with particles in which it is laid. This makes the egg very difficult to find in many foods.

The full-grown larva is 8 mm. long, somewhat flattened and sparsely covered with hairs. The general body color is yellowish-brown with head and posterior segments being a pronounced brown.

The pupa is white except for pigmentation of the eyes and mandibles. The color gradually darkens to light light brown before pupation. The males can be recognized by the conspicuously broadened mandibles.

The adult is shining reddish brown in color, about 4 mm. long. The antennae are clavate and sparsely covered with hairs. The mandibles of the female are short and of the regular coleopterous type but the mandibles of the male are conspicuously expanded at the base, extend forward and taper inward.

RESPONSES TO MOISTURE AND TEMPERATURE.—The adults were exposed in number of temperature and moisture environments (Table 1). In a favorable saturation deficit a temperature slightly above 32° or below 15° C. killed the beetles in a few days without reproduction occurring. The detrimental influence of high saturation deficits seemed more effective at high temperatures. At a number of the less favorable environments, beetles were able to survive the 14-day accustomation period and reproduce.

Since the food used made it difficult to

Table 1.—The environments in which the adults, larvae, prepupae, and pupae were exposed.

TEMP. °C.	SAT. DEF. MM.	(−)[1]	(•)[2]	TEMP. °C.	SAT. DEF. MM.	(−)[1]	(•)
12	3.5	—		25	20.7	—	
15	4.5	—	•	27	0.9	—	•
20	0.6	—	•	27	4.0	—	•
20	2.7	—	•	27	6.4	—	•
20	4.2	—	•	27	11.0	—	•
20	7.7	—	•	27	11.7	—	•
20	10.5	—	•	30	1.0	—	•
20	10.8	—	•	30	4.8	—	•
20	11.2	—	•	30	7.5	—	•
20	11.7	—	•	30	11.9	—	•
20	13.8	—	•	30	14.0	—	•
25	0.8	—	•	30	19.0	—	•
25	3.6	—	•	30	19.6	—	•
25	5.9	—	•	30	20.4	—	•
25	8.0	—	•	30	21.3	—	•
25	10.4	—	•	30	23.9	—	
25	12.1	—	•	30	25.0	—	
25	14.0	—	•	31	4.7	—	•
25	14.9	—	•	32	5.1	—	•
25	15.3	—	•	32	8.1	—	•
25	15.6	—	•	35	6.1	—	
25	16.0	—	•	37	6.9	—	
25	19.0	—		37	11.0	—	

[1] (−) Indicates the environments in which the adults were exposed.
[2] (•) Indicates the environments in which the larvae, prepupae, and pupae were exposed.

[1] The author wishes to express his sincere gratitude to Dr. Harvey L. Sweetman for his valuable advice and supervision, and to others who assisted him in completing this work.

locate the eggs, an indication of the number of the eggs laid per female was obtained by counting the larvae produced by one female. The greatest number of larvae obtained from a female was about 360 in a period of 5 months. The adult beetles live a total of about 8 months under optimum conditions.

The incubation period of the egg varies from 5 to 8 days at 20° to 30° C. in favorable moisture conditions; at the high saturation deficits at temperatures from 20° to 30° the larvae had difficulty in emerging from the egg, and the chorion remained attached for a period of time.

The larvae developed well in most environments where hatching occurred, except in 0.9 mm. and 1.0 mm. saturation deficit areas at temperatures of 27° and 30° C. (Table 1). The food in the low saturation deficit areas, where, in two environments no larvae survived, became infested with fungi. It may be possible that the fungi were responsible for the death of the larvae. The larval period increased by approximately 5 times as the temperature of the environment decreased from 32° to 15° C. at a saturation deficit between 4 and 5 mm. A high saturation deficit lengthened the larval period slightly. The percentages of the larvae surviving in the environments tested were very high, which shows a wide tolerence to temperature and moisture, particularly the latter.

All the larvae were reared in groups except four, which were placed in separate vials 4.5 mm. in diameter. Two of these larvae were given 0.025 gm. of food and, the other two had 0.018 gm. plus added food in the fifth instar. The temperature was 27° C. and the moisture 6.4 mm. The larvae with 0.025 gm. of food required 25 days for the larval period. The other two larvae required 30 days for the larval stage and 8 days for the pupal period. These periods, compared to twice recorded group data in this environment of 39 days for the larvae and 10 days for the pupae, are noticeably short. The reason for the shortened periods is not understood, but wherever larvae were crowded the periods were greatly lengthened.

The prepupal stage required 2 days and the pupal period 10 days. Since it appeared that the effects of moisture and temperature were similar on the prepupal and pupal stage, therefore these stages were grouped together. These stages were very sensitive to moisture, the percentage survival decreasing sharply above 8 with no survival at or above 19 mm. Temperature did not have any apparent effect from 20° to 32° C.

PROTHETELY.—The condition known as prothetely, or where an immature stage develops characteristics of the following more advanced stage, was observed. Sixteen larvae were found with wing pads projecting in varying degrees from the body. The larvae were allowed to develop, although some died in the prepupal stage. Those that did pupate had varying types of wing pads some with abnormal conditions of the eyes, mandibles, and legs; though a few appeared normal. Variously modified adults emerged with abnormalities in the elytra, hind wings, legs, mandibles, and eyes, though a few of the adult from all visible indications seemed to be normal.

Prothetely was observed in four different environments. One larva was subjected to the following conditions: temperature 30° C.; saturation deficit 7.5 mm.; food, a mixture of corn meal and meat-bone meal; alone in a single cage. Each day the larva was examined microscopically; a weak light was used. Five larvae were obtained under the following conditions: room temperature of 26° C.; saturation deficit approximately 7.0 mm.; food, corn meal and meat-bone meal; cage infested with mites. The conditions under which nine more larvae were found: temperature 25°; saturation deficit 5.9 mm.; food in rather poor condition. The last larva was obtained under: temperature of 20°; saturation decit 11 mm.; food, Haydak's mixture; larva in a slightly crowded condition with a number of other larvae.

CONCLUSIONS.—*Gnathocerus cornutus* can live and reproduce in a number of cereal and animal products. It did best in a food mixture based on Haydak's formulation plus meat-bone meal. The favorable temperature and moisture environments ranged from 15° to 32° C. and nearly zero to 12.7 mm. saturation deficit. The optimum temperature and moisture needs are near 24° to 30° C. and 2.5 to 7.5 mm. saturation deficit. The prepupal and pupal stages were most sensitive to marginal physical environmental conditions.

Development in the optimum zone required 7 days for the incubation period, 40 days for the larval development during which time the larva moults seven times, and 10 days for the pupal development. The preoviposition period consumed 20 days, making a total of about 77 days from egg to egg. A female will lay from 300 to 400 eggs in about 5 months under favorable conditions.—12-2-48.

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Effects of Weather, Sanitation and Chlorinated Chemical Residues on House and Stable Fly Populations on Nebraska Farms[1]

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Since L. O. Howard's (1906) early report on house flies many entomologists have conducted research on these insects. Their reports range from notes on the hibernation of house flies, *Musca domestica* L., to lengthy papers on the biology and control of house flies and stable flies, *Stomoxys calcitrans* (L.). Early control studies stressed the importance of sanitation, screening and the use of mist type contact insecticides. These standard control measures have not, however, received much attention in the United States since Wiesmann (1943) reported on the prolonged effectiveness of a new insecticide "*Gesarol.*" Scores of other workers have also published on the use of this material, now known as DDT, for the control of flies. Today our knowledge of this chemical in relation to flies is steadily increasing.

Early experiments with DDT in this country were necessarily confined to laboratory and small scale field tests. Among the early publications, however, were reports on the practical control of flies. Van Leeuwen (1944) reported practical destruction of house fly populations following single barn treatments while Blakeslee (1944) obtained little or no control of stable fly populations outside of treated barns and only a 12-day effective period on the inside.

The experiments reported in this paper were conducted during the summers of 1947 and 1948. They were designed to obtain information on the comparative efficiency of residual building sprays of DDT, methoxychlor methoxychlor, dichlorophenyl dichloro-ethane, chlorinated camphene and chlordan for house fly and stable fly control in milk barns; to study the effect of sanitary practices on house fly and stable fly populations in treated milk barns and to determine the comparative efficiency of chlorinated chemical residues as barn treatments and complete premises treatments. A preliminary report of the 1947 tests was made by Muma & Hixson (1948) but results were considered to be inconclusive.

PROCEDURE AND METHODS.—To assure adequate fly populations throughout the test period only dairy farms were selected for the experiments. It was felt that the animal populations on hog, sheep or cattle feeding farms and grain farms might vary sufficiently during the season to cause undesirable fluctuations in the total fly population. Dairies were selected at random irrespective of the number of milking animals. All dairies were located within a 20-mile radius of Lincoln, Nebraska.

Ten farms were used in the 1947 experiments. Only milking barns and loafing sheds were treated on each farm. Two farms were treated with each of the fol-

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lowing insecticidal formulations: 2.0 per cent water suspension of DDT from 50 per cent wettable powder,[1] 2.0 per cent water suspension of methoxychlor from a 50 per cent wettable powder,[2] 2.0 per cent water suspension of dichlorodiphenyl dichloroethane from a 50 per cent wettable powder,[3] 2.0 per cent water suspension of chlordan from a 50 per cent wettable powder[4] and 2.0 per cent water emulsion of chlorinated camphene from a 25 per cent emulsion concentrate.[5] All treatments were applied as sprays from a greenhouse type power sprayer at about 60 pounds pressure through a three nozzle spray broom equipped with number 4 disk openings.

Walls and ceilings were sprayed until the surfaces were wet just short of run-off. No attempt was made to determine the deposit of the insecticides on the various surfaces treated. Wall and ceiling surfaces varied within barns and between barns including unpainted wood and concrete, painted wood and concrete and various types of wall board.

In the 1948 experiments, 38 dairy farms were treated. Six different insecticidal formulations were used both as barn and complete premises treatments. An additional formulation was used solely as a barn treatment. DDT as a 2.0 per cent water suspension from a 50 per cent wettable powder[3] was used for three barn and four premises treatments. Dichlorodiphenyl dichloroethane as a 2.0 per cent water suspension from a 50 per cent wettable powder[3] was used for 3 barn and 3 premises treatments. Methoxychlor as a 2.0 per cent water suspension from a 50 per cent wettable powder[2] was used for 3 barn and 3 premises treatments. Chlordan as a 2.0 per cent water suspension from a 50 per cent wettable powder[6] was used for 3 barn and 3 premises treatments. Chlorinated camphene as a 2.0 per cent water emulsion from a 50 per cent emulsion concentrate[5] was used for one barn treatment. A mixture of 10.0 per cent piperonyl butoxide and 0.50 per cent pyrethrins at a rate of 8 pounds of a 25 per cent wettable powder per 100 gallons of water[7] was used for 3 barn and 3 premises treatments for the initial spraying and at 2-week intervals as barn treatments on the same six farms for the duration of the experiment. The piperonyl butoxide-pyrethrin mixture was used repeatedly at this sub-residual concentration to test the effect of a quick knockdown contact insecticide on fly populations. All original treatments were applied as sprays from an orchard type power sprayer at about 200 pounds pressure through a single nozzle, trigger type spray gun with a number 6[1] disk opening. Later treatments of piperonyl butoxide-pyrethrin were applied with the equipment used in 1947. Surfaces were sprayed until run-off occurred. Treatments designated as barn treatments consisted of an inside spraying of the entire barn that housed the milking room. Premises treatments consisted of a complete spraying of all barns, sheds, wind breaks, feeding racks, trees, shrubs and fences in the farm lay out.

Fly populations were sampled at weekly intervals in the milking rooms and adjacent loafing sheds only. Sampling consisted of trapping flies on fly paper ribbons[8] exposed for 24 hours on hanging strips of lath or lattice. Each lath exposed one-third of a square foot of trapping surface. One square foot of trapping surface was exposed for every 1000 square feet of ceiling in the milking room and directly connecting loafing sheds or rooms. The proportion of trapping surface to ceiling area was calculated to the nearest one-third square foot and ribbons were hung at regular intervals within the sample areas. House flies, stable flies and other flies were recorded on each one-third square foot sample unit following each 24 hour exposure period. Trapping surfaces were removed following each exposure period and were renewed each week. The objections to such a sampling method were fully recognized but it was felt that recordings would be considerably more accurate than those obtained by the commonly used population estimations, unit area (square foot or yard) counts, short exposure period traps or attractants as used by Brett & Fenton (1946) or electric fly traps. Location of the sample units restricted analyses of results obtained to conditions within the milking barns.

[1] Pennsylvania Salt Co., Philadelphia, Pa.
[2] Du Ponts, Wilmington, Del.
[3] Rohm & Haas, Philadelphia, Pa.
[4] Dow Chemical Co., Midland, Mich.
[5] Hercules Powder Co.
[6] Velsicol Corporation, Chicago, Ill.
[7] U. S. Industrial Chemicals, Inc., New York.
[8] Russell Sales & Mfg. Co., New York.

Sanitary conditions were recorded near the end of the test period for each season. A sanitation index was established to assure as nearly as possible a uniform evaluation of the several test farms. This index was based on use by the farmer of the following sanitary fly control measures: (1) frequency in cleaning the floor and gutter of the milking room and loafing shed, (2) frequency in removing and spreading manure piles, (3) the use of isolated frequently cleaned sheds and buildings as regular quarters for farm animals and (4) the destruction or removal of old hay and straw stacks, piles of bedding and silage and other obvious stable fly breeding sites. Farms using all four of these sanitary measures were given an excellent sanitation rating, those using 3 were rated good, those using two were rated fair and those using only one were rated poor. No farm failed to use at least one of these practices. Breeding sites for which the farmer was not directly responsible or over which he had no control were also included in the indexing. Among these were intermittently flowing or stagnant streams, temporary marshes or swamps and flash-flood debris.

WEATHER.—Temperature, rainfall and wind all greatly influence fly populations. This has been demonstrated by Bishopp (1913) for the stable fly and Bishopp *et al.* (1915) for the house fly. These factors have not, however, been given adequate consideration in analyses of chlorinated chemical control data. Only general, vague statements concerning weather and fly control appear in available literature.

Results obtained in the present study show that weather as expressed by temperature and rainfall may cause considerable variation in practical fly control data. Mean temperatures and rainfalls and resultant population changes for 1947 and 1948 are shown in figures 1 and 2 respectively. Certain fluctuations in fly populations may be correlated with these weather factors. House fly numbers varied directly with increases and decreases in mean temperatures after chemical treatments had lost their efficiency. As the tests were discontinued 5 to 6 weeks after the loss of chemical effectiveness little opportunity was afforded to study the combined effect of temperature and rainfall on house flies. Chemicals did not, however, appear to give prolonged control of stable flies and there was a distinct correlation between weather and population variations. The only fluctuations in stable fly populations that did not follow changes in temperature and rainfall were the depres-

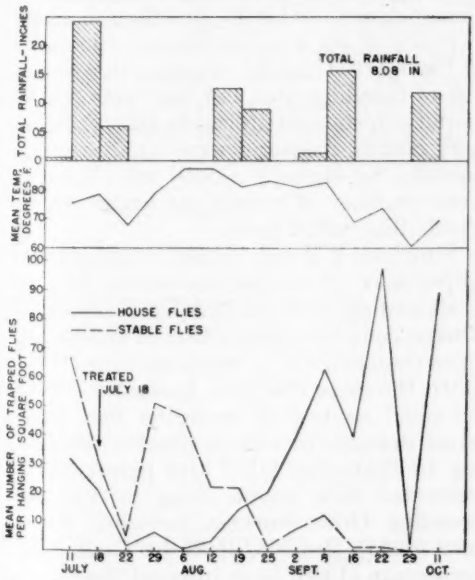

FIG. 1.—Fluctuations of house and stable fly populations following shifts in mean weekly temperatures and total weekly rainfalls at Lincoln, Nebraska. Summer, 1947.

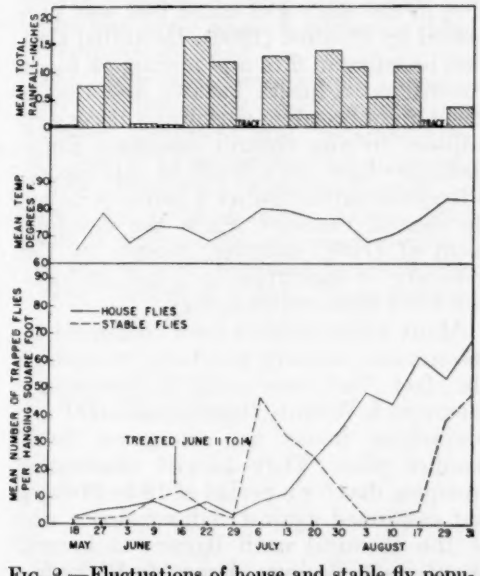

FIG. 2.—Fluctuations of house and stable fly populations following shifts in mean weekly temperatures and total weekly rainfalls in Lancaster County, Nebraska. Summer, 1948. Temperature and rainfall figures represent means of recordings at 5 official weather stations within the county.

sions obtained on August 25, 1947, and August 3, 1948. As these depressions succeeded similar population peaks of three weeks duration they may have been due to a biological cycle.

The influence of wind upon fly populations was not as striking as that of temperature and rain. No general population changes over an extended period of time appeared to be caused by this factor. There were, however, decided temporary effects on the isolated populations at each farmstead. The most easily observed was that on adult activity. On cool windy days few flies of either species were active and in some instances were found only on protected sun warmed walls. Warm windy days, on the other hand, seemed to drive the flies into the barns and sheds in large numbers. On either warm or cool windless days few flies were found within the barns. Temperatures and wind velocities causing these population habits were not recorded.

These data demonstrate the need for careful study of the weather during practical fly control experiments. Otherwise false control periods may be obtained when weather conditions are unfavorable to fly development and activity and apparent failure of chemical control may be obtained in favorable fly weather.

Sanitation.—The importance of sanitation in the control of house flies was suggested by Howard (1906), He stated that flies breeding in filth and feeding on foods constituted a health hazard, and that a clean up of breeding sites was a necessary adjunct to any control program. Entomologists have, as a result of this report, advocated sanitation as a primary house fly control measure. Since the development of DDT, however, reports on the necessity of sanitation in house fly control have been contradictory.

Many entomologists have continued to recommend sanitary practices, conceding the fact that sanitation is necessary. Simmons & Wright (1944) tested DDT for preventing house fly emergence from manure piles. They almost eliminated emerging flies for a period of 18 to 67 days but cautioned against indiscriminate use of the chemical until more was known about its toxicology. Bruce & Blakeslee 1946) were unable to duplicate these results reporting that "treatment of infested manure piles with DDT sprays as a supplement to barn spraying was only partly effective and is not considered of much practical value." They did, however, state that "the interior finish of the dairy building and the fly sanitation maintained on the premises were in most cases the limiting factors in the degree of control obtained."

Some entomologists have reported house fly control with DDT in the face of nearby breeding sites indicating that sanitation is not necessary. Wiesmann (1943) obtained 28 day complete control and 36-day practical freedom from flies despite an adjacent fly-breeding manure pile. Similar results were reported by Sweetman (1946) who controlled flies with spot treatments of 25 per cent DDT even though a nearby manure pile was not treated or removed Sweetman, however, made repeated spray applications, stating that heavy fly populations rendered the spray residue ineffective in as short a time as 3 to 5 days. In additional tests Sweetman was unable to prevent fly breeding in manure around a piggery and reported that rotation of feeding equipment prevented accumulation of manure.

Similar apparent contradictions on the importance of sanitation also appear in stable fly studies. In the grain belt Bishopp (1913) reported a close relation between rain, hay or straw stacks and stable fly outbreaks. King & Lenert (1936) demonstrated stable fly breeding in shore deposits of sea weed in Florida. Simmons & Dove (1941) added peanut litter to the list of breeding sites and Simmons (1944) found infestations in waste celery. Sanitary control measures were highly recommended by Bishopp (1939) who listed a large number of conditions under which stable flies would breed.

Simmons & Wright (1944) conceded the importance of controlling stable flies at the breeding sites and for 32 days obtained almost complete elimination of emergence from peanut litter by spraying with DDT. With the same chemical Blakeslee (1945) obtained control of emerging flies from shore deposits of marine grasses. According to Blakeslee, DDT also permanently protected this media from critical fly breeding. Other workers, including Wiesman (1943), Bruce & Blakeslee (1946) and Sweetman (1946) have inferred the unimportance of sanitation in reporting stable fly control without treating or removing adjacent breeding materials.

Sanitation has been considered important in all Nebraska fly control tests with chlorinated chemicals. Tate & Muma (1946) blamed apparent failure of DDT to control stable flies on incomplete treatment or the presence of nearby breeding sites. In 1947 an attempt was made to establish standards for measuring the possible effects of sanitation on fly populations in treated barns. Since then a sanitation index method of evaluation has been used to help analyze the fly populations. This index appears to result in more reliable data than the general observations so often used. Even more accurate records could probably be obtained with an index utilizing a longer series of standards. In addition to the standards previously discussed frequent cleaning of poultry houses elimination of permanent hog wallows, cleanliness and rotation of hog lots, frequent chemical treatment of outdoor toilets and regular scraping of the barn yard might also be utilized.

From the 1948 data presented in figure 3 it is apparent that sanitary conditions on the farmstead limit the effectiveness of chlorinated chemical residues on house fly populations. As all of the farms used for these data were treated with a chlorinated chemical the population peaks shown are probably considerable lower than would have been obtained under untreated conditions. The 1 to 4-week increase in control of house flies obtained by sanitary practices seems to be large enough to merit consideration. The shorter control periods obtained under unsanitary conditions may have been due to a masking of chemical effectiveness or to a covering or wearing away of the residues by the large fly populations. Sanitation data collected during 1947 gave the same trends as those figured for 1948 but were not considered to be conclusive due to the smaller number of barns, 10 in 1947 compared to 38 in 1948.

Stable fly populations apparently are not influenced by the sanitary practices used as standards in these experiments. Figure 4 gives the population trends for the several sanitation ratings in 1948. The lack of correlation between degree of sanitation and fly populations indicates the need for further studies on the breeding grounds, life history and migration habits of the stable fly in this area. Flies may be breeding in obscure or hidden places. It is also possible that farm sanitation may greatly reduce the number of flies but be offset by flies following animals from distant pastures or adjacent farmsteads.

CHLORINATED CHEMICAL RESIDUES.—There seems to be a considerable difference of opinion among the many workers as to what constitutes an effective chlorinated chemical control. This is evidenced by the fact that Sweetman (1946) stated that repeated DDT sprayings of selected spots at intervals of 3 to 10 days gave effective control of both stable flies and house flies while Bruce & Blakeslee (1946) "effectively checked" a stable fly outbreak for a period of control "conservatively estimated at 2 weeks" with a single premises treatment and "retained effective control (of house flies) for an average of 173 days" with single treatments in 4 ceiled and painted daries. Other differences in what constitutes an effective control period were reported by Wiesmann (1943), Blakeslee (1944), Van Leeuwen

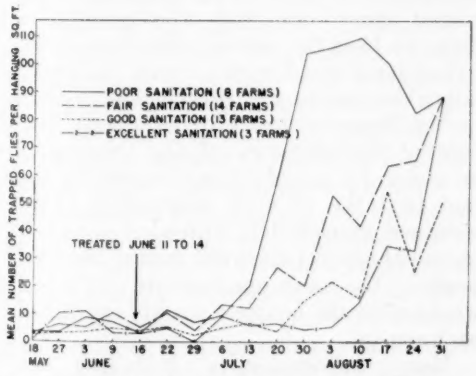
MEAN NUMBER OF TRAPPED FLIES PER HANGING SQ FT
POOR SANITATION (8 FARMS)
FAIR SANITATION (14 FARMS)
GOOD SANITATION (13 FARMS)
EXCELLENT SANITATION (3 FARMS)
TREATED JUNE 11 TO 14
18 27 3 9 16 22 29 6 13 20 30 3 10 17 24 31
MAY JUNE JULY AUGUST

FIG. 3.—Effects of sanitation on efficiency of chlorinated chemical residues in controlling house fly populations in milking barns, Lancaster County, Nebraska. Summer, 1948.

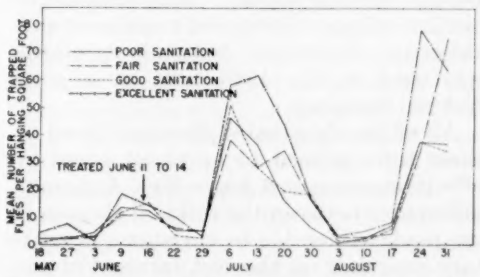
MEAN NUMBER OF TRAPPED FLIES PER HANGING SQUARE FOOT
POOR SANITATION
FAIR SANITATION
GOOD SANITATION
EXCELLENT SANITATION
TREATED JUNE 11 TO 14
18 27 3 9 16 22 29 6 13 20 30 3 10 17 24 31
MAY JUNE JULY AUGUST

FIG. 4.—Effects of sanitation on efficiency of chlorinated chemical residues in controlling stable fly populations in milking barns, Lancaster County, Nebraska. Summer, 1948.

Table 1.—Effect of residual barn treatments of fly populations in the milking rooms and directly connecting loafing rooms or sheds in 1947.

Treatment	Mean Number of Trapped Flies per Hanging Square Foot in 24 Hours											Farm Sanitation		
	Treatment Date July 18													
	July				August			September						
Fly Species	11	18	22	29	6	12	19	2	9	16	22	Poor	Fair	Good
Wettable DDD 2.0 per cent														
House flies	34.5	15.6	0.6	5.4	0.9	7.8	13.8	66.6	24.3	65.1	39.0	1		1
Stable flies	65.4	30.9	5.4	27.6	33.0	16.5	11.4	0.0	3.0	0.9	0.0			
Wettable DMDT 2.0 per cent														
House flies	48.0	21.6	2.1	3.9	1.5	2.4	18.3	9.6	108.9	74.1	155.4		1	1
Stable flies	136.8	30.3	7.4	36.6	17.4	14.4	14.4	3.6	15.9	0.3	1.8			
Emulsion Chlorinated Camphene 2.0 per cent														
House flies	73.9	57.6	0.9	6.9	0.9	3.9	20.4	11.4	55.8	28.8	94.8		2	
Stable flies	99.0	67.8	3.0	59.4	50.1	28.2	24.3	1.8	10.8	3.0	0.3			
Wettable DDT 2.0 per cent														
House flies	12.0	6.0	0.0	5.7	1.5	1.5	6.6	3.3	72.0	20.1	63.6		1	1
Stable flies	42.0	11.7	6.0	55.2	41.1	14.4	12.0	0.7	4.5	1.8	0.0			
Wettable Chlordane 2.0 per cent														
House flies	3.9	3.6	6.0	10.8	0.9	0.6	12.9	9.6	53.4	18.0	134.7		1	1
Stable flies	106.8	17.4	3.0	77.1	93.6	38.4	48.3	1.8	27.3	0.3	2.4			

(1944), Brett & Fenton (1946) and Stage (1947).

Reports on the effectiveness of DDT for the practical control of house flies and stable flies are far too numerous to cite here. There have, however, been few previous reports on the practical effectiveness of chlorinated chemicals, other than DDT, in the control of house flies and stable flies. Sweetman (1947) obtained comparable practical control periods with dichlorodiphenyl dichloroethane and DDT while Bruce & Decker (1947) reported that no practical difference in fly reduction occurred between chlordan, dichlorodiphenyl dichloroethane and DDT used on dairy farms and animals.

Tables 1 and 2 present the data accumulated for the past two seasons on the comparative practical effectiveness of DDT, methoxychlor, dichlorodiphenyl dichloroethane chlorinated camphene and chlordan. Piperonyl butoxide-pyrethrin was used in the 1948 tests as a non-residual fly spray.

All of the chlorinated chemicals used in these tests seemed to be about equal in effectiveness against house flies. Apparent differences between the residual chemicals are readily referable to variations in sanitary practices on the test farms. For example dichlorodiphenyl dichloroethane in 1947 gave a comparatively short control period on house flies whereas chlordan in 1948 gave a comparatively long control. An examination of the sanitation data, however, shows that one of the two barns treated with dichlorodiphenyl dichloroethane in 1947 had the only poor sanitary rating given during that season whereas chlordan was used on the only three farms rated with excellent sanitation in 1948.

Although all of the chlorinated chemicals tested appeared to depress the stable fly population, the control obtained is not believed to be economical. An apparent control of less than 2 weeks duration was recorded in 1947. This reduction in population could not, however, be attributed entirely to the chemical treatments as a marked fall in the mean temperature occurred coincident with the population drop. In 1948 the control period appeared to last for 2 and 3 weeks. Again the population depression was preceded by a drop in the temperature. Further doubt concerning the efficiency of the treatments on stable fly populations is raised by the fact that the seasonal population peaks obtained immediately following apparent chemical control occurred during seasonal peaks of the mean temperature and 1 to 2 weeks after the heaviest weekly rainfall of each season.

Many entomologists, including the present authors, have followed the findings of Bruce & Blakeslee (1946) in recommending complete premises treatments over barn or spot treatments. It is, in fact,

Table 2.—Effect of residual barn and premises treatments on fly populations in the milking rooms and directly connecting loafing rooms and sheds in 1948.[1]

Treatment	Mean Number of Trapped Flies per Hanging Square Foot in 24 Hours											Farm Sanitation			
	Treatment Date June 14														
	June			July				August				Poor	Fair	Good	Excel.
Fly Species	8	21	28	5	12	19	29	2	9	16	23				
Wettable DDD 2.0 per cent															
House flies	11.4	21.0	3.9	14.7	16.8	25.5	20.4	91.5	39.0	39.0	36.0		4	2	
Stable flies	15.0	9.1	3.9	32.4	27.3	43.8	9.3	1.8	0.6	6.0	20.7				
Wettable DMDT 2.0 per cent															
House flies	2.7	3.6	3.6	6.3	9.3	4.8	24.6	21.6	18.0	79.2	48.9	1	3	2	
Stable flies	3.1	2.1	1.2	26.7	19.2	10.8	6.3	6.3	0.9	3.6	40.5				
Emulsion Chlorinated Camphene 2.0 per cent[2]															
House flies	12.4	7.9	4.6	11.5	5.5	8.6	4.4	10.2	26.2	86.2	30.5		4	3	
Stable flies	14.2	6.1	7.6	61.5	45.7	35.9	12.0	3.1	3.0	4.8	20.6				
Wettable DDT 2.0 per cent															
House flies	5.2	2.5	2.1	3.6	7.8	11.4	35.4	36.0	43.8	40.5	72.6	3	3	1	
Stable flies	8.1	3.3	1.2	21.6	20.4	1.8	4.2	1.8	2.1	2.4	27.6				
Wettable Chlordane 2.0 per cent															
House flies	10.2	2.4	0.6	6.9	6.0	6.9	4.5	2.7	6.6	28.2	22.8	1		2	3
Stable flies	23.4	24.6	1.5	48.9	49.0	43.8	21.0	3.3	6.3	7.2	79.8				
Wettable Piperonyl butoxide-pyrethrum 0.25 per cent															
House flies	4.5	13.5	5.4	12.0	22.7	93.6	124.8	213.3	127.7	123.9	89.7	3	1		
Stable flies	11.1	5.4	9.6	91.5	37.1	10.1	14.7	1.5	1.8	7.8	40.5				

[1] Data on barn and premises treatments have been combined.
[2] One barn treatment was made with a 25 per cent wettable powder.

logical to conclude that the treatment of all or nearly all of the apparent fly resting places on a farmstead will result in a better control of flies.

In order to obtain some local fly control figures, 20 of the farms included in the 1948 experiments were given complete premises treatments. The resultant data, expressed in means of the fly populations, are given in figure 5. Apparently premises treatments had no significant additional influence on the number of flies that enter the milking barns. This should not be considered to infer that such treatments would not be much more effective than barn or spot treatments in reducing fly numbers throughout the farmstead. There is a need for further extensive studies of the relation of fly migration and fly breeding grounds to the comparative effectiveness of chlorinated chemical residues as spot, barn and premises treatments. Flies migrating unknown distances from previously undiscovered breeding grounds have an important bearing upon the practicability of the three different types of treatment. If flies are, as shown by Hodge (1913), migrating long distances from known breeding sites to the animals and

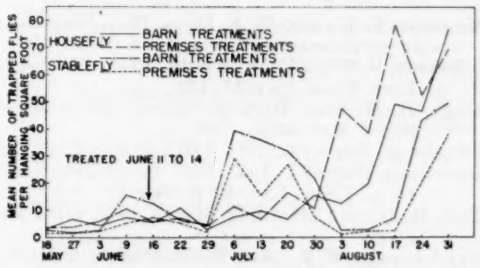

FIG. 5.—Comparative efficiency of barn treatments and complete premises treatments with chlorinated chemical residues in controlling house and stable fly populations in milking rooms, Lancaster County, Nebraska. Summer, 1948.

thence to the farmstead, spot treatments of farm buildings and removal of the breeding media might give control. At the other extreme, flies moving locally from unknown breeding sites might be little affected even by premises treatments.

SUMMARY.—House fly populations on Nebraska farms increase in the presence of moderate to heavy rains, high temperatures and poor sanitation but decrease with a lack of rain, low temperatures and excellent sanitation. Good fly breeding and development weather and the pres-

ence of adequate breeding media mask the effect and reduce the efficiency of chlorinated chemical residues. Stable flies are similarly affected by weather but do not appear to be strongly influenced by farm sanitation. Under comparable practical conditions DDT, dichlorodiphenyl dichloroethane, methoxychlor, chlorinated camphene and chlordan all seem to give a comparable control of house flies and stable flies. Chlorinated chemicals used as residual building treatments do not give an effective control of stable flies at the dilutions used. Barn and premises treatments seem to be equally effective in reducing the number of house flies and stable flies that enter the milk barns on treated farms.

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OSCAR MONTE

In Rev. Brasil. Biol. 8(3): 411–2 we find a note contributed by A. M. da Costa Lima stating that Oscar Monte died on July 1, 1948, at his home in Belo Horizonte.

Born in 1895, Dr. Monte was formerly Professor of Entomology at Belo Horizonte and was more recently a member of the staff of the Instituto Biologico at San Paula. He was a great authority on the Tingitidae and was the author of numerous papers on other Hemiptera and on Coleoptera and Lepidoptera.

In 1928 Dr. Monte published the "Almanack Agricola Brasileiro" a work on the common names of insects in Brazil and in 1934 he published the manual "Borboletos que vivem em plantes cultivadas." His work on the Tingitidae was never completed.

J. L. CARTLEDGE

Low Pressure Spraying Equipment for Control of Some Forage Insects[1]

J. T. Medler and T. R. Chamberlin[2]

Since the so-called "weed" sprayers are becoming a standard item of equipment with many general farmers and custom operators, it seemed desirable to test them for the application of recently developed insecticides. The rapid utilization of low pressure machines for the spraying of herbidices has made available on farms many machines which might be used for the spraying of insecticides, provided they are proved suitable or can be easily modified for this purpose. Heretofore the spraying of insecticides has been largely restricted to expensive high pressure machines on farms with relatively high value per acre orchard and row crops.

The low pressure sprayer can either be home made (Bruhn & Berge 1948a) or bought commercially at a relatively low cost. The practical application of insecticides with low pressure sprayers would enable the general farmer to utilize low cost machinery for both insect and weed control. Such a use would seem feasible especially where the purchase of high cost spray machinery for treatment of relatively low value crops would not be economical.

Comparative data between high and low pressure spraying are not presented here since the primary objective of these experiments was to test the practicality of low pressure machines in our forage insect control program. Experiments were made in the field in conjunction with studies on legume seed production.

In 1947, Medler & Chamberlin (1948) showed that seed yields if red and ladino clovers were increased by the use of insecticides. The insecticides used in their experiments were applied with low pressure sprayers supplied by farmer cooperators. Applications of spray were made at about 30 lbs. pressure and 100 gallons per acre.

During the 1948 season tests were made to evaluate types of pumps, wettable powders and emulsions and determine the limits of reduced volume. Applications to field plots were made as uniformly as possible with a sprayer mounted on a Chevrolet panel truck. A twenty foot boom of 1.25 inch seamless steel tubing was mounted on the front bumper of the truck. The boom was adjustable in height from 24 to 36 inches and carried 13 nozzles spaced 20 inches apart. Single-piece fan-type nozzles with an orifice of 0.039 inch and 80 mesh screen were used. Agitation was supplied by a by-pass from the pump.

A centrifugal-jet pump was used to apply sprays on June 10 and 11 to a heavy stand of knee-high alfalfa grown for seed on a farm in Sheboygan County. Application was made at 30 to 40 lbs. pressure and approximately 15 gallons per acre. Wettable powders and emulsion concentrates of chlordan and chlorinated camphene were compared. The average counts of the alfalfa plant bug, *Adelophocoris lineolatus* (Goeze), obtained in four samples of four sweeps for each treatment are given in table 1.

Table 1.—Numbers of alfalfa plant bugs in Sheboygan County alfalfa plots treated June 10–11, 1948, with low pressure equipment at the rate of 15 gallons per acre.

Spray Material	Average Number per Sweep of 15 Inch Net		
	June 17	June 29	
	Nymphs	Adults	Nymphs
Chlordan, 50% wettable powder, @ 1 lb. technical per acre	0	1.0	0
Chlordan, 50% emulsion concentrate, @ 1 lb. technical per acre	0	2.0	0
Chlorinated camphene, 40% wettable powder, @ 1½ lb. technical per acre	.25	2.0	0
Chlorinated camphene, 50% emulsion concentrate, @ 3 lb. technical per acre	0	3.5	0
Untreated check	22.8	11.2	16.2

The data given in table 1 show that very good control of the alfalfa plant bug was obtained with chlordan and chlorinated camphene at the dosages tested. The doubled amount of chlorinated camphene emulsion was applied through erroneous use of 50 per cent rather than 25 per cent concentrate, but data obtained in other experiments show that effective

[1] Supported in part by the Research Committee of the Graduate School of the University of Wisconsin from funds supplied by the Wisconsin Alumni Research Foundation.

[2] Wisconsin Agricultural Experiment Station and U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, respectively.

control would be expected with the 1.5 lbs. per acre dosage. No difference in initial effectiveness of the wettable powders and emulsions was detected but a loss of residual effectiveness of the emulsions was suggested for adults in the counts made 18 days after the materials were applied.[1]

A rotary gear pump was used to apply sprays on June 11 to a heavy stand of knee-high alfalfa on a farm in Fond du Lac County. Application was made at 40 lbs. pressure and approximately 30 gallons per acre. The same materials used in the preceding experiment were applied, but the amount of toxicant per acre was doubled. This dosage was heavier than planned because the gear pump maintained a 40 lbs. pressure, instead of more nearly 30 lbs., and apparently had more capacity for delivery of liquid than the jet pump. Average counts of alfalfa plant bugs obtained in 2 samples of 4 sweeps for each treatment are given in table 2.

The data given in table 2 show the complete absence of nymphs and reduced numbers of adults in treated plots 17 days after the insecticides were applied. The loss of residual effectiveness of the emulsion for control of adults is indicated for both materials. The high count of adult bugs in the chlorinated camphene emulsion plot is perhaps explained by randon sweeps made in an area subject to recent migration from the untreated check.

Table 2.—Numbers of alfalfa plant bugs in Fond du Lac County alfalfa plots treated June 11, 1948, with low pressure equipment at the rate of 30 gallons per acre.

Spray Material	Average Number per Sweep 15 Inch Net	
	June 28	
	Nymphs	Adults
Chlordan, 50% wettable powder, @ 2 lb. technical per acre	0	1.5
Chlordan, 50% emulsion concentrate, @ 2 lb. technical per acre	0	4.0
Chlorinated camphene, 40% wettable powder, @ 3 lb. technical per acre	0	2.0
Chlorinated camphene, 50% emulsion concentrate, @ 6 lb. technical per acre	0	7.5
Untreated check	4.7	8.5

Experiments with second growth alfalfa were made in Outagamie County. Insecticides were applied August 3 in a ran-

[1] Although no exact yield of seed was obtained, it was learned from the farm superintendent that a strip harvested with a combine in the untreated alfalfa for the full length of a plot (120 rods) gave about 8 inches of seed in a standard seed bag and that a similar strip in treated alfalfa practically filled a bag. From this it is estimated that the treated alfalfa produced about 5 times as much seed as the untreated.

Table 3.—Number of insects in 16 sweeps of a 15 inch net per treatment in Outagamie County alfalfa plots treated August 3, 1948, with low pressure equipment at the rate of 20 gallons per acre.

Spray Material	August 12			August 26		
	Plant Bugs		Grass-hoppers	Plant Bugs		Grass-hoppers
	Adults	*Nymphs*		*Adults*	*Nymphs*	
DDT—25% emulsion concentrate @ 1 lb. technical per acre	4		31	22	4	25
DDT—20% Chlordan—45% emulsion conc. @ 1 lb. technical per acre	8		3	17	14	6
Chlordan 36% emulsion conc. @ 1 lb. technical per acre	6	1	0	26	24	7
Chlorinated camphene—43.5% emulsion conc. @ 1.5 lb. technical per acre	7		12	13	17	14
DDT—50% wettable powder @ 1 lb. technical per acre	3		21	17	1	23
Chlordan—50% wettable powder @ 1 lb. technical per acre	7		2	8	17	4
Chlorinated camphene—40% wettable powder @ 1.5 lb. technical per acre	7	1	1	36	7	8
Untreated check	13	7	33	25	20	25

domized block of eight treatments in four replicates. The gear pump at 30 to 35 lbs. pressure and 20 gallons per acre was used. Counts of plant bugs and grasshoppers are given in table 3. The plant bugs include *Adelphocoris lineolatus* (Goeze), *A. rapidus* (Say), and *Lygus oblineatus* (Say).

The initial insect counts in table 3 show that reduction of plant bugs took place with all materials tested, but DDT was superior. Grasshoppers were reduced by chlordan and chlorinated camphene formulations, whereas DDT showed little effectiveness. The loss of residual action on plant bugs over a 3 week period is shown for the chlordan and chlorinated camphene by increased counts of nymphs. The low count of nymphs in DDT plots is indication of residual effectiveness. The counts of adults doubtless are less reliable because of migration between the plots, which were only 21 feet wide. The numbers of grasshoppers reduced by chlordan and chlorinated camphene were still evident in counts made 3 weeks after the application of insecticides. There also is indication that wettable powders show more residual toxicity than emulsions for all materials tested.

Data obtained from other experiments made in 1947 and 1948 are not given, but all evidence secured during those years supports our conclusions that forage insects can be controlled with low pressure spraying equipment. This equipment has the practical advantage of low gallonage application. For example, we usually applied about 20 gallons of spray to an acre in about 5 minutes, using a 20 foot boom, 35 to 40 lbs. pressure and 13 nozzles with .039 inch orifice. With a tank capacity of at least 100 gallons and a readily available water supply, it is apparent that many acres can be treated in a day's time. However, the efficient application of insecticides to forage crops with low pressure equipment depends upon the proper interrelationship of characteristics peculiar to the machine, the operator and the insecticide formulation. Two years of experience with low pressure sprayers has enabled us to determine certain desirable and undesirable features which are briefly discussed.

Boom.—The most satisfactory boom length appears to be not less than 20 and not more than 30 feet. A shorter length covers less area per trip and may result in excessive crop loss by tracking. Booms longer than 30 feet must be braced to prevent whipping and on rough terrain the ends may catch on the ground. Desirable features are: easily adjustable height, clean-out plugs at each end, quick and simple mounting on vehicle, folding design for road travel or passage through gates, reinforcement at nozzle threads, and construction from a material that is sturdy and adaptable to welding repairs.

Nozzles.—Many types of nozzles are available. A one-piece nozzle was found to be satisfactory in our experiments. We found in the four-piece nozzle with changeable discs little merit that is justified by the price difference. It is desirable to have nozzles with strainers, especially when wettable powders are being used. Flat fan spray types of 60° to 85° spray angle gave satisfactory performance in our tests. A desirable feature is a numbering system for nozzles that corresponds directly with the orifice opening, *e.g.*, #39 = 0.039 inch orifice.

Pumps.—It appears at this time that insecticides can be applied with any type of pump providing that adequate pressure and gallon delivery is attained. We have observed satisfactory insect control by sprayers with centrifugal-jet, flexible impeller, piston and rotary gear pumps. The bronze gear and flexible impeller pumps are the most commonly used types in low pressure sprayers. Both are compact and relatively inexpensive. The gear pump is durable and self-priming and may be operated at a variable pressure range. There is a possibility of abrasion injury, hence precaution with wettable powders is indicated. The flexible impeller type of pump is more limited in effective pressure range than the gear pump. Perhaps a desirable feature is non-abrasion, but the neoprene rubber impeller is not recommended for use with xylene formulations of DDT.

Agitation.—The majority of low pressure sprayers have inadequate agitation for the wettable powders of the newer insecticides. Agitation is usually supplied by a by-pass from the pump. Most pumps are of low capacity and barely accommodate the boom delivery, hence give insufficient by-pass for agitation. Poor suspensions cause non-uniform coverage, which is especially critical at low volume rates of

application. Better insect control probably can be obtained with sprayers having limited capacity pumps if emulsions are used instead of wettable powders. Nozzle clogging that is caused by poor physical properties of wettable powders or emulsions can be reduced by the incorporation of a line filter between the tank and pump. The use of larger capacity pumps for by-pass agitation and a larger nozzle orifice may also reduce nozzle-clogging difficulties, more prevalent with wettable powders. According to Bruhn & Berge (1948b) the pump should have a capacity of at least 13 gallons per minute at 30 pounds pressure for a 20 foot boom.

Formulation.—Our data show that satisfactory initial control of some forage insects with low pressure spraying is accomplished with either wettable powders or emulsions. Emulsions appear to lose residual effectiveness sooner than wettable powders. However, many of the wettable powders we have tested do not remain well in suspension, clog nozzles, thereby causing non-uniform coverage, and contain gritty particles that may abrade gear type pumps. We have observed also that many wettable powders applied at ordinary low pressures do not spread well on legumes.

Rate of application or dosage.—The proper rate of spray application or dosage of insecticides is the fundamental basis for the practical control of forage insects with low pressure spraying. The rate of application in gallons is determined by the speed of vehicle, nozzle spacing and nozzle discharge. Nozzle discharge is determined by pressure and nozzle orifice. Formulation of insecticide as a wettable powder or emulsion may also determine rate of application, since our observations show that wettable powders are delivered at a more variable rate than emulsion-when low gallonages are used. This varis ability may be due to partial clogging of screens by the powder. It appears from a practical standpoint that the variable factors in the rate of application are secondary to dosage per acre of the toxicant. We have obtained satisfactory control at pressures of 30 to 150 pounds, vehicle speeds from 3 to 8 miles per hour, and nozzle orifices from .022 to .059 inch. Rates of application have varied from 15 to 100 gallons of spray per acre.

The dosage is determined by the spray tank concentration of toxicant in relation to the rate of application. Satisfactory control has been obtained with dosages of 1 lb. technical DDT or chlordan, or 1.5 lbs. technical chlorinated camphene per acre.

Precautionary statement.—It is probable that the same low pressure sprayer will be used for both weed and insect control. Residues of herbicides left in the tank and sprayer may in subsequent spraying injure crop plants. The weed-killing chemicals should be removed with a chemical cleaner and adequate rinsing before the sprayer is used for insecticides. A practical measure would be the use of separate metal tanks for weed sprays and insect sprays.

Conclusions.—Low pressure spraying equipment was tested in 1947 and 1948 for the application of the newer insecticides to forage crops for control of certain injurious insects. Reduced numbers of these insects or increased yields of legume seed were obtained in treated plots and demonstrated that low pressure spraying was practical for this purpose.

Tests were made to evaluate different types of sprayers and pumps, compare wettable powder and emulsion formulations of insecticides, and determine the most effective rates of application.

Most pumps we have tested have insufficient capacity. It is estimated that for a 20-foot boom, a capacity of about 13 gallons per minute, at 30 lbs. pressure would be sufficient. The larger pump not only allows increased volume, but also provides extra capacity for by-pass agitation of wettable powders.

Insecticides may be applied as wettable-powder suspensions or emulsions with satisfactory results providing equivalent dosages of toxicant are maintained. There is an indication that emulsions lose their residual effectiveness before wettable-powder sprays. The use of an emulsion is perhaps more desirable in sprayers with limited capacity pumps.

Very good control of forage insects was obtained at 30 to 40 lb. pressures and 15 to 30 gallons per acre. The method of application appears to be secondary to dosage per acre of the toxicant. Dosage of 1 lb. technical DDT or chlordan, or 1.5 lbs. technical chlorinated camphene appears to be satisfactory for the control of many forage insects.

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Effect of Dispersing and Spreading Agents on Toxicity of DDT Spray Powders

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The effect of wetting and spreading agents on residue types of spray is still controversial in spite of a rather large amount of research. Steiner *et al.* (1944) found that addition of a wetting agent to DDT mixtures did not improve, and in many cases reduced, toxicity to codling moth larvae. However, there are important advantages from their use and it seemed advisable to make a further study of their effects on DDT toxicity in an attempt to resolve the divergent points of view.

DDT, and likewise many diluents, are insoluble in water and a small amount of additive gives better suspension. Diluents vary in their wetting power, however, and not all require the same amount of wetting agent to produce a good suspension. Surfaces of plants vary in the way they are wet, and addition of a wetting agent helps to wet some waxy surfaces. Yarwood (1937) found that addition of a spreader to bordeaux mixture improved its performance on onion leaves which are very difficult to wet.

Wetting agents also improve spray coverage. Smith (1926) found that by adding casein lime and calcium hydrate to lead arsenate sprays on apples he could improve the spray coverage by lowering surface tension. However the additional coverage effected by the use of spreading agents did not improve control of codling moth larvae 2 years later (1928). Therefore Smith advanced the following five possible theories for its failure to improve control: (a) casein was not compatible with the arsenic; (b) the film of toxicant broke owing to the growth of the fruit, allowing larvae to enter on the unprotected surface; (c) the lime in the spreader acted as a diluent which lowered the effectiveness of the arsenic residue; (d) addition of a spreader did not improve spray coverage; and (e) the actual film resulting from the spreader was too thin.

A sixth possible cause for failure of a wetting agent to improve control, which Smith did not mention, is lack of deposition. Addition of wetting agents to DDT spray powders decreases the initial deposit (Turner & Woodruff 1946). Reduction of surface tension results in smaller spray droplets which do not reach the sprayed surface.

Smith's work, of course, was with arsenate of lead sprays. We know that most spreaders are compatible with DDT, and we would not expect the breaking of the toxic film on leaf surface to be a factor because of the frequency of application of DDT sprays. Relative spray volumes are not of sufficient magnitude to cause any spreader to act as a diluent which might lower DDT toxicity. Therefore, we can assume that only two of Smith's factor are involved, either that addition of a spreader does not improve coverage or that the initial film produced by the spreader is too thin.

Coverage was thoroughly investigated by Smith in his study of 1928, when he found that a fine spotted type of coverage resulting from use of a spreader did not protect the fruit from codling moth injury. A spotty, coarse coverage was more desirable than a less concentrated film protection since the probability of killing the larvae with the amount of toxicant present was greater than the probability of their finding it at all. This was also demonstrated in 1948 by Turner & Woodruff. The same amount of DDT was applied to glass slides, but the area treated was varied. After exposing the slides to house flies, they discovered that mortality was greater as the same amount of DDT was applied to smaller areas. In other words, a heavy deposit concentrated on a small area was more effective than

the same amount of toxicant spread out over an area twelve times as large.

In addition to Steiner's work on the failure of wetting agents to improve DDT toxicity, Woodruff & Turner (1946) also found that they reduced control of flea beetles when added to DDT sprays on potato foliage, and also affected final yield. In another study the same authors found that while addition of a wetting agent reduced deposit, there didn't seem to be any marked loss in toxicity with wetter than without.

Another important effect of a wetting agent upon DDT toxicity, which earlier workers overlooked, is tenacity. Fajans & Martin (1937) studied the physical properties of spray deposits which affected the efficiency of protective insecticides and fungicides. They said that tenacity was greater on surfaces which wetted with difficulty, and addition of supplements which were highly surface-active, caused decreased tenacity. Horsfall (1945), in discussing tenacity of fungicides, also confirmed this observation when he stated that "other things being equal, the most soluble fungicide should be the most toxic and the least tenacious."

The presence of a wetting agent in a residue type of spray allows it to be more easily wetted by water, which results in greater loss of deposit by washing, according to Shepard (1939). More recently, Kovache & Ficheroulle (1948) found that commercial additives with bordeaux would improve the wetting power of the spray and initial retention, but had no effect on tenacity. However, when they increased the concentration of the wetting agent to 4 to 10 times the recommended dose, they found that, while retention and wetting power were unchanged, tenacity was reduced because of increased wettability of deposit.

LABORATORY RESULTS.—The function of a true wetting agent is to lower surface tension of water so that it will readily wet a dry concentrate with a minimum of stirring. Wetting agents used in this work were polyethylene glycol phenylisooctyl ether,[1] and a sodium salt of sulfonated ethylmethyl oleylamide.[2] Since previous work has shown that lowered surface tension results in smaller droplet size, it was decided also to include in this study two dispersing agents which do not lower surface tension and therefore should not affect droplet size. Two polymerized sodium salts of alkyl aryl sulfonic acids[3] were used.

Laboratory procedure was the same as that outlined by Woodruff & Turner (1947). DDT was applied to glass lantern slides by means of a precision sprayer designed after the apparatus of Hoskins as described by Richardson (Campbell & Moulton 1943). Sprayed surfaces were dried 24 hours and exposed to 25 to 30 5-day old house flies. After an exposure period of 1 hour, the flies were held for 24 hours and then mortality counts were made.

In order to demonstrate the effect of amounts of additives on DDT toxicity, two dispersers and one wetting agent were added in water to a DDT constant of .0625 per cent. A 50 per cent DDT powder with a diatomaceous earth as diluent, was used. Dosages of additives ranged from .25, .5, 1.0, and 2.0 per cent, based on water volume. Table 1, and figure 1, show that regardless of the nature of the additives, all reduce toxicity in a typical dosage response; the more additive, the lower the toxicity. Of course, it should be remembered that amounts of additives are extremely large. At these high levels, although the toxicity of DDT is less affected by amounts of one of the dispersing agents[4] than the other two materials, nevertheless there is a reduction in toxicity at all levels, based on 90 per cent mortality of a DDT suspension without an additive. Since there was a definite pattern between amount of additive and toxicity, it was decided to determine the effect of very much lower dosages of dispersing and wetting agents to DDT toxicity.

Accordingly, the dispersing agents[5] and the wetting agent[6] respectively were incorporated, at the rate of 1 per cent, into 50 per cent mixtures of DDT and a clay[7] by hammer-milling.[8] In order to determine whether method of preparation would infiuence toxicity, these same agents were added to DDT-clay water suspension at the same rate of the dry mixture.

Results of the tests in which additives were incorporated into a dry mixture

[1] *Triton X-100.*
[2] *Igepon-T-Powder.*
[3] *Darvan 1* and *Darvan 2.*
[4] *Darvan 2.*
[5] *Darvans* 1 and 2.
[6] *Triton X-100.*
[7] Continental Clay.
[8] Acknowledgement is made to the R. T. Vanderbilt Research Laboratory for processing of all materials used

Table 1.—Effect of increasing amounts of additives on DDT toxicity to house flies.

Material	DDT Conc.	Additive Conc.	Per Cent Mortality 1	2	Mean
Diat. earth-DDT+ dispersing agent[1]	.0625	0	91	90	90
		.25	80	67	74
		.5	66	56	62
		1.0	55	44	49
		2.0	36	18	27
Diat. earth-DDT+ dispersing agent[2]	.0625	0	91	90	90
		.25	83	85	84
		.5	80	83	81
		1.0	77	80	78
		2.0	65	65	65
Diat. Earth+ wetting agent[3]	.0625	0	91	90	90
		.25	56	53	55
		.5	51	50	50
		1.0	50	41	45
		2.0	48	33	40

[1] *Darvan 1.*
[2] *Darvan 2.*
[3] *Igepon-T-Powder.*

show essentially the same kill as those in which the agents were added to a water suspension (Tables 2 and 3, Figure 2). The presence or absence of either a dispersing or a wetting agent did not affect DDT toxicity appreciably. All preparations were about equally effective, but one of the dispersing agents[1] again appears to have slightly more toxicity although this is not significant. It is obvious, then, at this low concentration of additive, that surface tension has not been lowered enough to affect the DDT deposit in the case of the wetting agents. The dispersing agents do not affect surface tension anyway; therefore all preparations act alike.

TENACITY.—Very little mention has been made of the effect of dispersing and wetting agents on tenacity of DDT. In the

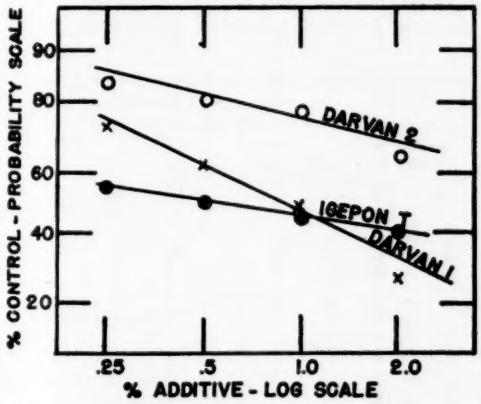

FIG. 1.—Toxicity to house flies of two dispersers and one wetting agent added in a dosage series to DDT onstant of .0625. (1. *Darvan 2*; 2. *Darvan 1*; 3. *Igepon T*)

Table 2.—Effect of small amounts of additives incorporated into DDT dry mixtures on toxicity to house flies.

Material	DDT Conc.	Per Cent Mortality 1	2	3	4	Mean
Clay-DDT	.125	95	77	91	73	92
	.0625	89	62	81	56	72
	.0312	56	58	38	23	44
	.0156	45	27	29	23	31
Clay-DDT dispersing agent[1] (1%)	.125	96	95	100	87	95
	.0625	86	82	73	54	74
	.0312	62	53	80	46	60
	.0156	54	29	24	12	30
Clay-DDT dispersing agent[2] (1%)	.125	100	100	100	100	100
	.0625	94	83	92	72	85
	.0312	80	55	77	41	63
	.0156	40	26	31	23	30
Clay-DDT wetting agent[3] (1%)	.125	100	88	100	81	92
	.0625	69	80	92	56	74
	.0312	41	35	78	31	46
	.0156	20	16	0	27	16

[1] *Darvan 1.*
[2] *Darvan 2.*
[3] *Triton X-100.*

laboratory, glass lantern slides were weighed, sprayed, dried and re-weighed for actual deposit. Then they were washed in cold water using a geometric series of strokes from 4 to 32, a modified technique of Heuberger (1940). After drying another 24 hours, slides were weighed again and the per cent tenacity calculated.

We know that large amounts of wetting agents added to DDT water suspensions deposit less as concentration is increased, wash off rapidly and cause loss both in toxicity and in tenacity. Table 4 shows what happens to tenacity when dispersing agents are added to water suspensions of DDT and diluent in increasing amounts. The DDT constant in all cases is 0.5 per cent. Unlike wetting agents, both dispersers deposit heavier as concentration is increased, possibly because they are not

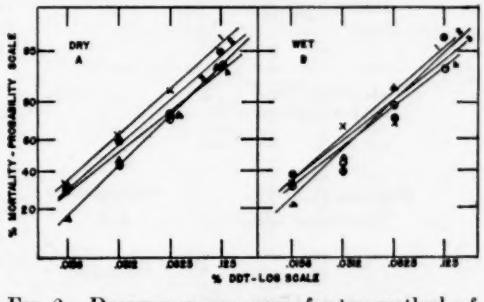

FIG. 2.—Dosage response curves for two methods of adding spreading and dispersing agents. A. additives milled into dry DDT grind. B. same agents added to DDT water suspension at same dosage as A. (1. DDT+*Darvan 2;* DDT+*Triton X-100;* 3. DDT+*Darvan 1;* 4. DDT and diluent alone.) Laboratory tests against house flies.

Table 3.—Effect on toxicity to house flies of small amounts of dispersing and wetting agents added to DDT water suspensions.

Material	DDT Conc.	Add Conc.	Per Cent Mortality 1	2	Mean
Clay-DDT[1]	.125		100	81	91
	.0625		75	82	78
	.0312		38	50	44
	.0156		19	45	32
Clay-DDT	.125	.0025	100	93	97
+dispersing agent[2]	.0625	.00125	82	62	72
	.0312	.0006	38	42	40
	.0156	.0003	41	35	38
Clay-DDT	.125	.0025	100	100	100
+dispersing agent[3]	.0625	.00125	100	40	70
	.0312	.0006	75	60	67
	.0156	.0003	48	17	32
Clay-DDT	.125	.0025	100	100	100
+ wetting agent[4]	.0625	.00125	89	82	85
	.0312	.0006	67	29	48
	.0156	.0003	30	14	22

[1] Continental Clay.
[2] *Darvan 1.*
[3] *Darvan 2.*
[4] *Triton X-100.*

surface-active. However these dispersers reduce tenacity very rapidly. Obviously they have some properties which keep the DDT particles suspended in water and these same properties may enable the water to wash off the residue. Since the DDT concentration is extremely high for toxicity tests with houseflies, only those slides at the extremes of the washing levels were exposed to flies, and the time of exposure was reduced to 30 minutes to compensate for the high dosages. The very high mortalities in all cases indicate that the remaining deposit must be substantially pure DDT, the additive and the diluent washing off independently. Since DDT is extremely tenacious by itself this is not surprising.

Another tenacity test was made of the two dispersing agents after they had been incorporated into the dry mixture of Clay

Table 4.—Tenacity of dispersing agents added to DDT water suspensions in increasing amounts, and toxicity to house flies.

Material	Per Cent Conc.	Initial Deposit mg.	No. Strokes Washed	Remaining Deposit mg.	Per Cent Tenacity	Per Cent Kill
Diat. earth-DDT	.5	55	4	30	55	100
		49	8	22	55	
		70	16	35	50	
		54	32	16	30	94
Diat. earth-DDT	.5	78	4	16	21	100
Dispersing agent[1]	.5	75	8	15	20	
		71	16	8	11	
		73	32	9	12	100
Diat. earth-DDT	.5	93	4	7	8	91
Dispersing agent[1]	1.0	98	8	8	8	
		99	16	7	7	
		93	32	6	6	85
Diat. earth-DDT	.5	147	4	3	2	95
Dispersing agent[1]	2.0	146	8	5	4	
		139	16	6	4	
		139	32	5	3	88
Diat. earth-DDT	.5	75	4	5	7	100
Dispersing agent[2]	.5	85	8	8	9	
		89	16	7	8	
		78	32	6	7	92
Diat. earth-DDT	.5	100	4	10	10	89
Dispersing agent[2]	1.0	99	8	9	9	
		98	16	5	5	
		99	32	2	2	84
Diat. earth-DDT	.5	160	4	3	2	100
Dispersing agent[2]	2.0	156	8	1	1	
		143	16	1	1	
		141	32	1	1	75

[1] *Darvan 1.*
[2] *Darvan 2.*

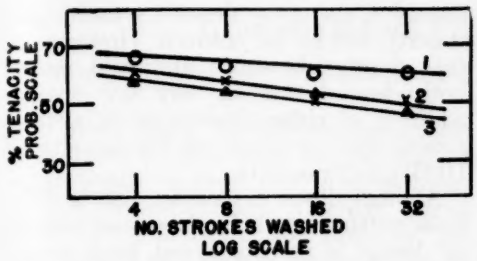

FIG. 3.—Tenacity of three DDT mixtures, one without additive and two containing 1 per cent by weight of dispersing agent. (1. DDT and diluent alone; 2. DDT+*Darvan 1;* 3. DDT+ *Darvan 2.*)

and DDT at the rate of 1 per cent dry weight.

Table 5, figure 3 shows that all materials deposit alike, with or without an additive, but that the presence of the dispersing agents still reduces tenacity slightly, even at this low concentration. It will be remembered that in toxicity tests, addition of a slight amount of dispersing agent caused a small increase in toxicity. By keeping the concentration of the disperser as low as possible, the additional toxicity gained by its use will offset its slight loss in tenacity.

FIELD RESULTS.—In the field in tests on control of potato flea beetles, one dispersing agent,[1] the wetting agent,[2] and both together, were added to 50 per cent DDT-Clay[3] mixtures at the rate of 1 per cent, by hammer-milling, as was done for laboratory work. All mixtures were applied to 15-foot plots of Katahdin potatoes which were randomized in four blocks. Potatoes were planted May 4 and sprayed weekly from June 8 to July 26 as described by Woodruff & Turner (1947). Materials

Table 5.—Tenacity of DDT mixtures containing one per cent dispersing agent.

MATERIAL	DDT CONC.	MEAN DEPOSIT mg.	NO. STROKES WASHED	PER CENT TENACITY 1	2	Mean
Clay	.5	44	4	68	64	66
			8	59	66	63
			16	58	62	60
			32	55	65	60
Clay-DDT +dispersing agent[1] (1%)	.5	44	4	64	58	61
			8	59	55	57
			16	49	53	51
			32	49	52	51
Continental Clay-DDT +dispersing agent[2] (1%)	.5	42	4	58	58	58
			8	59	50	54
			16	52	52	52
			32	47	45	46

[1] *Darvan 1.*
[2] *Darvan 2.*

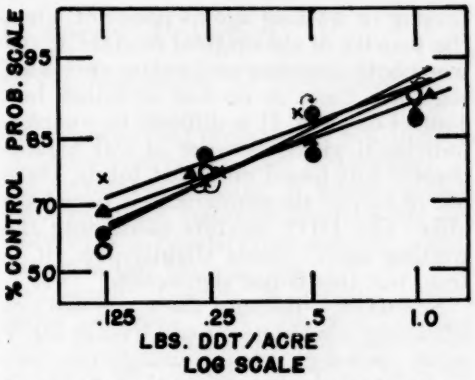

FIG. 4.—Control of potato flea beetles with mixtures of DDT containing small amounts of additives. (O=DDT+diluent alone; ●=DDT+*Darvan 2*; ▲=DDT+*Triton X-100*; X=DDT+*Triton X-100* and *Darvan 2* together.)

were applied at the rate of 1, 0.5, 0.25 and 0.125 pounds DDT per 100 gallons of water.

Flea beetle damage for both the first and second generations was estimated using a scoring system described by Horsfall (1945).

Table 6 gives per cent control of flea beetles based on damage to the untreated check, and final yields in pounds of each plot. Curves for second generation flea beetles are plotted in figure 4. These results confirm those in the laboratory, that addition of small amounts of either dis-

[1] *Darvan 2.*
[2] *Triton X-100.*
[3] Continental Clay.

Table 6.—Results of field tests of DDT mixtures containing dispersing and wetting agents

MATERIAL	DDT CONC. LBS.—100 GALS.	PER CENT CONTROL FLEA BEETLES 1st Gen.	2nd Gen.	YIELD IN LBS.	TOTAL YIELD lbs.
Clay-DDT	1.0	87	91	103	
	.5	64	89	111	
	.25	63	78	109	
	.125	52	57	118	443
Clay-DDT +dispersing agent[1] (1%)	1.0	72	88	127	
	.5	62	82	99	
	.25	45	82	117	
	.125	45	61	106	452
Clay-DDT +wetting agent[2] (1%)	1.0	72	91	110	
	.5	75	84	112	
	.25	69	77	104	
	.125	65	69	101	428
Clay-DDT dispersing[1] and Wetting agent[2] (1%)	1.0	79	90	121	
	.5	65	89	124	
	.25	50	78	102	
	.125	50	77	106	454

[1] *Darvan 2.*
[2] *Triton X-100.*

persing or wetting agents does not affect the toxicity of the original mixture. Even when both disperser and wetter are added together, there is no loss in either bug control or yield. It is difficult to compare individual yields because of soil heterogeneity but based on grand totals, three out of four of the combinations tested are alike. The DDT mixture containing the wetting agent yields slightly less, it is true, but this is not significant.

SUMMARY.—Because there are distinct advantages in the use of additives in DDT spray powders, this investigation was undertaken to examine the divergent conclusions resulting from previous work on their use. Since there is a definite relationship between dosage of wetting agent and response, it seemed advisable to study their effects on residues at very much lower dosages.

If the concentration of the additive is excessive, the spray deposit, tenacity and toxicity will all be reduced. However, in this study, laboratory and field results both showed that at very low dosages addition of either dispersing or wetting agents had no effect on the toxicity of DDT spray powders.

At high doses, dispersing agents differ from wetting agents by depositing heavier as dosage is increased, yet both reduce tenacity sharply. At low concentrations however, addition of either dispersing or wetting agent has no effect on DDT deposit and offsets its slight loss in tenacity by maintaining high toxicity.

If amounts of additives can be kept at a minimum, it is possible to capitalize on their properties of producing better dispersability and ease of suspension without loss in either toxicity or tenacity of the DDT residue.

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AIRPLANE INSECT CONTROL COURSE AT PURDUE

A Short Course for Airplane Sprayers and Dusters was held at Purdue University on March 10 and 11, 1949. Over 100 attended, mostly from Indiana but Illinois, Wisconsin, Kentucky, Michigan, Connecticut, Florida and Ohio were represented. Subjects covered included the principles of insect control, airplane dusting and spraying, equipment, legal aspects, ethics, airplane application of fertilizers, seeds, etc.

Concentrated DDT Spray Powders

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A great many insecticides have been formulated so that they can be applied substantially in their pure form without the use of inert carriers. Arsenate of lead and calcum arsenate, for example, are used almost exclusive of inactive ingredients. Since DDT softens at temperatures below 88° C., as Chisholm (1945) has pointed out, manufacturers have found it necessary to dilute the pure compound with dry inert diluents to a concentration of 50 per cent or less. This practice of highly diluting the active insecticide with inerts has been in wide general use. It seemed of interest to study the effects of smaller amounts of diluents on DDT toxicity, mixtures containing at least 80 per cent active ingredient.

Salzberg *et al.* (1945) formulated water dispersible non-caking powders which contained at least 90 per cent DDT. These powders were prepared by micronizing DDT, an anti-caking agent, a dispersing agent, and a wetting agent. Chisholm (1948) reviewed the formulation of DDT high concentrates and showed that DDT powders containing as high as 97 per cent DDT could be prepared by micronizing the compound and then coating the particles with a film-forming agent to prevent caking during storage.

There has been little mention made of the comparative effectiveness of these highly concentrated DDT mixtures and the conventional 50 per cent standard spray powders. In 1946 two dispersible DDT powders, each containing 90 per cent DDT, were prepared by the Insecticide Division of the Bureau of Entomology and Plant Quarantine, A flowable powder, A, contained 90 per cent technical DDT, and 10 per cent silica aerogel,[1] while the other, B, a wettable powder, contained 90 per cent DDT, 8 per cent silica aerogel[1] and 2 per cent wetting agent.[2] In toxicity tests on houseflies in this laboratory, material B, which contained a wetting agent, was highly superier to A possibly because B was more easily dispersed in water than A. B was also as toxic as a standard 50 per cent wettable powder at the same DDT concentration. A preliminary tenacity test showed that preparation A withstood light washing better than B. However, at heavy rates of washing, B showed higher tenacity. Both materials compared favorably with a standard commercial preparation in this tenacity test.

Recently, Gooden & Updike (1948) have reported on three-year storage tests of these same 90 per cent DDT powders and found that there was no deterioration at room temperature and very little at temperatures of 55° C.

PREPARATION OF MATERIALS.—Three types of concentrated DDT water dispersible powders were studied in the laboratory. The first was made up of 83.5 per cent DDT, 8.25 per cent Talc and 8.5 per cent of a complex colloidal magnesium aluminum silicate.[3] Hereafter, this highly refined product will be referred to as colloidal silicate in this paper. It possesses excellent properties as a sticking, dispersing and suspending agent, and was used without addition of any surface-active agent. This mixture was prepared by wet ball-milling, drying at low temperatures and then careful hammer-milling. The resulting product was a dry powder, readily water dispersible and free-flowing on standing. The second and third preparations combined 90 per cent DDT with 10 per cent silica aerogel.[4] The two types of silica aerogel used in these tests differed only in physical form A[5] has a larger particle size and greater density than B,[6] while B has been compressed to reduce bulk for convenience in handling. These samples were ground with DDT by micronizing on a 24 inch micronizer at a feed rate of 900 pounds per hour. The average actual DDT particle size was about 2.5 microns.

TENACITY OF DILUENT.—In the laboratory, the three diluents used were sprayed in suspension at 0.5 per cent on glass slides. The slides were weighed, sprayed, dried, and then re-weighed for actual deposit. Then they were washed in tap

[1] *Santocel 45.*
[2] *Igepon AP Extra.*
[3] *Veegum* obtained from and processed by R. T. Vanderbilt Research Laboratories, East Norwalk, Conn.
[4] Obtained from and processed by Merrimac Div. of Monsanto Chemical Co., Boston, Mass.
[5] *Santocel CF.*
[6] *Santocel C.*

water using a geometric series of strokes from 4 to 32, a modified technique of Heuberger (1940). After drying in a dessicator, slides were weighed again and per cent tenacity calculated. These diluents used in concentrated DDT mixtures were compared with a diatomaceous earth, representative of a diluent used in standard preparations of 50 per cent DDT spray powders.

Both silica aerogels and the colloidal silicate exhibited much greater tenacity than the standard diluent (Table 1, Fig. 1). Silica aerogel B was by far the most tenacious. In our various studies of diluents for 50 per cent DDT spray powders, the general pattern has been low tenacity of the diluent itself, but toxicity tests have failed to show that this low tenacity was of any great disadvantage (Turner & Woodruff, 1948).

Table 1.—Tenacity of pure diluent.

Material	Conc.	No. Strokes Washed	Per Cent Tenacity
Colloidal Silicate[1]	.5	4	91
		8	76
		16	75
		32	68
Silica aerogel B[2]	.5	4	94
		8	88
		16	88
		32	74
Silica CF aerogel A[3]	.5	4	71
		8	74
		16	68
		32	67
Diatomaceous earth	.5	4	45
		8	40
		16	31
		32	29

[1] *Veegum.*
[2] *Santocel C.*
[3] *Santocel CF.*

As yet we do not know the effect of tenacity on the toxicity of DDT concentrates, but the fact that all three diluents used in this study were extremely tenacious might be significant. With concentrated DDT powders, where the diluent comprises even less of the total mixture, the choice of diluents is limited chiefly by the requirement that they keep DDT particles finely divided.

LABORATORY RESULTS.—In the laboratory, residue tests were made by spraying

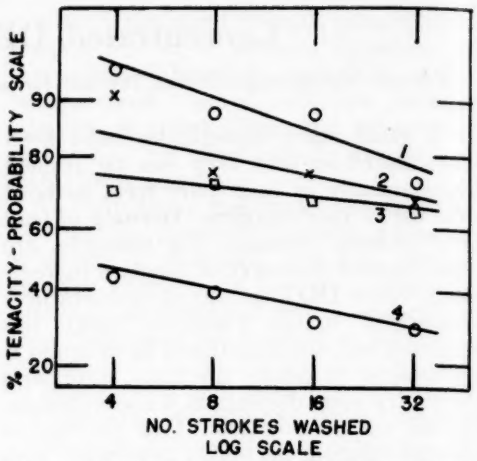

FIG. 1.—Tenacity of diluents used in concentrated DDT powders compared with diluent used in 50 per cent powder. 1. Silica aerogel B; 2. Colloidal silicate; 3. Silica aerogel A; 4. Diat. earth.

glass lantern slides and exposing them to house flies, a technique already described by Woodruff & Turner (1947). Dosage-response tests were made comparing the concentrates with a standard 50 per cent DDT spray powder. The DDT concentrations were 0.125, 0.0625, 0.0312, and 0.0156 per cent, with a constant spray time of 10 seconds. The mean toxicities (Table 2, Fig. 2) are the average of six exposures for each material.

Silica aerogel A and the colloidal silicate preparations show greater toxicity than the standard 50 per cent powder (significance $>.01$ by the Wilcoxon (1947) method of analysis). Silica aerogel B is not significantly better than the 50 per cent powder, although it would appear so on

Table 2.—Laboratory tests on house flies of concentrated DDT powders and standard 50 per cent powder.

Material	DDT Conc.	Per Cent Mortality 1	2	3	Mean
Colloidal silicate-DDT 83.5%	.125	100	100	78	93
	.0625	75	76	66	72
	.0312	51	45	41	44
	.0156	33	28	37	33
Silica aerogel B-DDT 90%	.125	86	86	93	88
	.0625	57	68	60	62
	.0312	39	49	48	45
	.0156	21	25	30	25
Silica aerogel A-DDT 90%	.125	98	100	100	99
	.0625	73	87	75	78
	.0312	48	63	52	54
	.0156	30	31	36	32
Clay—DDT 50%	.125	73	97	93	88
	.0625	56	67	74	65
	.0312	23	39	42	34
	.0156	22	19	18	19

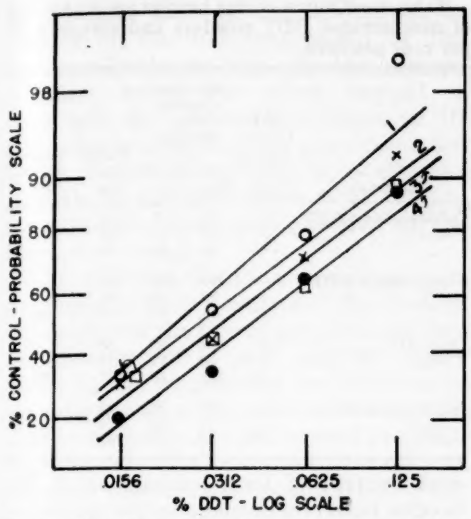

FIG 2.—Toxicity to house flies of three concentrated DDT powders and a standard 50 per cent DDT mixture. Diluents: 1. Silica aerogel A; 2. Colloidal silicate; 3. Silica aerogel B; 4. Clay.

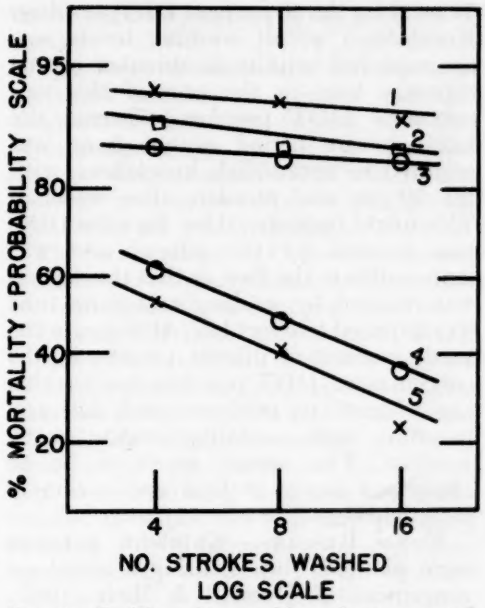

FIG. 3.—Toxicity after washing of concentrated and standard powders, at constant DDT concentration of .125 per cent. Diluents: 1. Silica aerogel A; 2. Silica aerogel B; 3. Colloidal silicate; 4. Clay; 5. Diatomaceous earth.

the dosage-response curve. It is interesting to note that sample A with a DDT particle size of 2.15 microns was more toxic that B with a DDT particle size of 2.33 (Woodruff & Turner, 1947). Particle size was not determined for the colloidal silicate-DDT preparation, and although it is slightly less toxic than silica aerogel A-DDT, this also is not significant by the Wilcoxon method. The colloidal silicate preparation suspended well in water whereas the silica aerogel-DDT samples required prolonged mixing in a Waring blender, and constant agitation while sprayed.

Table 3.—Toxicity to house flies of concentrated DDT powders and standard 50 per cent powders after washing.

MATERIAL	DDT CONC.	NO. STROKES WASHED	PER CENT MORTALITY		
			1	2	Mean
Colloidal silicate-DDT 83.5%	.125	0	97	91	94
	.125	4	83	90	87
	.125	8	86	84	85
	.125	16	88	84	86
Silica aerogel B-DDT 90%	.125	0	92	95	94
	.125	4	85	94	89
	.125	8	87	83	85
	.125	16	88	83	86
Silica aerogel A-DDT 90%	.125	0	91	95	93
	.125	4	92	94	93
	.125	8	92	93	92
	.125	16	91	90	90
Clay-DDT 50%	.125	0	77	72	74
	.125	4	62	62	62
	.125	8	50	49	49
	.125	16	37	33	35
Diatomaceous earth-DDT 50%	.125	0	67	65	66
	.125	4	52	55	54
	.125	8	39	42	41
	.125	16	24	21	23

To test the effect of tenacity on toxicity of concentrated DDT residues, these same materials were compared with two 50 per cent DDT powders, one with a clay as diluent, and the other containing a diatomaceous earth. The DDT dosage was kept constant at 0.125 per cent, and each series was washed in water at 4, 8, and 16 strokes. From the data (Table 3, Fig. 3) all concentrated DDT preparations have maintained extremely high toxicity after washing, the dosage-response curves being flat and parallel, whereas the two 50 per cent powders have lost effectiveness rapidly at each level of washing, the dosage-response curves being steep and parallel. The order of toxicity of the concentrated DDT mixtures differs from the tenacity of the pure diluent. Silica aerogel B for instance, had the highest tenacity as a diluent, but did not produce greatest toxicity after washing when combined with DDT. The amount of washing used has affected the toxicity of the concentrates very little, the per cent mortality between 0 and 16 strokes ranging from 95 to 85, while the range is

72 to 23 for the 50 per cent DDT powders. Knockdown at all washing levels was accomplished within 15 minutes of the exposure time in the case of the concentrated DDT powders, whereas the full exposure period of one hour was required to accomplish knockdown with the 50 per cent powders after washing. This might indicate either that the DDT was covered by the diluent and was inaccessible to the flies, or that the deposit was reduced by washing and more time was required to effect kill. At any rate the small amount of diluent present in the concentrated DDT powders has enabled the toxicant to produce quick kill and maintain high mortality despite heavy washing. This should prove to be an important factor in field application of insecticides.

FIELD RESULTS.—Katahdin potatoes were planted May 4, using a spiral arrangement of Horsfall & Rich (1947). The technique used was that reported by Turner (1948). Eight applications of DDT were made from June 11 to July 30. For late blight, tribasic copper sulfate, at the rate of 2 pounds to 50 gallons of water, was applied to all plots on August 16, and zinc dithane at 1 pound to 50 gallons to all plots on August 20.

Damage by flea beetles was estimated on June 25 for the overwintering adult and on July 20 for the summer generation using the scoring system described by Horsfall (1945). Final yields were dug in October. Table 4, figure 4 shows the per cent control of two generations of flea beetles based on damage to the untreated check. Only the most toxic silica aerogel-DDT mixture (A) was tested in the field. Colloidal silicate-DDT was also compared with the two standard 50 per cent powders one containing a clay as diluent, and the other a diatomaceous earth.

Table 4.—Control of flea beetles and final yield of concentrated DDT powders and standard 50 per cent powders.

Material	DDT Conc. Lbs. 100 Gals.	Per Cent Control Flea Beetles 1st Gen.	2nd Gen.	Yield in Lbs.	Total Yield lbs.
Colloidal silicate-DDT 83.5%	1.0	97	94	55	
	.5	85	92	62	
	.25	78	84	72	189
Silica aerogel A-DDT 90%	1.0	80	89	57	
	.5	80	88	60	
	.25	81	85	63	180
Clay-DDT 50%	1.0	88	89	55	
	.5	72	84	74	
	.25	75	76	47	176
Diatomaceous Earth-DDT 50%	1.0	89	87	65	
	.5	83	85	52	
	.25	80	77	61	178

During the spraying operation it appeared that most of the silica aerogel mixture was not suspended in the spray tank, forming a scum on the surface of the water. The poor suspending qualities of silica aerogel have already been discussed, and it was not possible to equal laboratory conditions in the field. Agitation in the spray tank was not sufficient), therefore poor suspension probably accounts for its relatively poorer performance

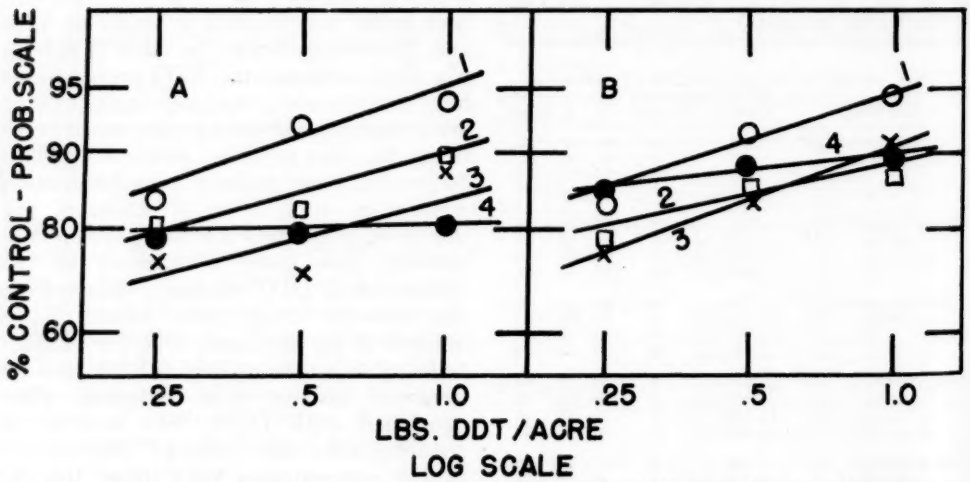

FIG. 4.—Control of potato flea beetles with concentrated and standard DDT powders. A—first generation. B—second generation. Diluents: 1. Colloidal silicate; 2. Diatomaceous earth; 3. Clay; 4. Silica aerogel A.

in the field than in the laboratory. In control of the first generation of flea beetles (Table 4, Fig. 4), the dosage-response curve for silica aerogel is extremely flat, probably because of its poor suspension. Second generation flea beetle control shows it to be as effective as both 50 per cent powders at the top concentration and more effective at the two lower dosages.

The colloidal silicate concentrate gave significantly better control of flea beetles than either of the two 50 per cent powders (significance $>.01$), and slightly higher yield. At the 90 per cent control level of second generation flea beetles, it was twice as effective as the two 50 per cent powders, 0.45 pound DDT of the concentrate equalling control of 1.0 pound DDT of the standards.

SUMMARY.—Three concentrated DDT spray powders, containing at least 80 per cent active ingredient, were compared with standard 50 per cent powders.

In the laboratory on house flies all concentrates showed greater toxicity than the 50 per cent powders at the same DDT dosage.

The three diluents used in the concentrated powders, a complex colloidal magnesium aluminum silicate and two silica aerogels, were much more tenacious than a diatomaceous earth which was selected as a representative of diluents used in 50 per cent powders.

The concentrated DDT powders showed much greater toxicity after washing than two standard 50 per cent powders.

Two out of three concentrated DDT powders were used in the field to control potato flea beetle in comparison with two standard 50 per cent DDT mixtures. The colloidal silicate preparation produced significantly better control of flea beetles, both over-wintering and summer generations, than the two standard powders, In contrast with laboratory results, silica aerogel-DDT was only equal to the standard 50 per cent powders in flea beetle control. A flat dosage-response curve of silica aerogel indicated that possibly poor suspension was involved.

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APPLE GOES TO WISCONSIN

J. W. Apple of the University of Illinois has been appointed associate professor in the department of economic entomology of the College of Agriculture, University of Wisconsin. Mr. Apple received his training at Ohio State University and Iowa State College. He has been working on corn borer and vegetable crop research. His new duties at Wisconsin will be canning crop research, especially on corn and peas.

Development of Precision Instruments for Artificial Insemination of Queen Bees

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The queen honey bee mates in flight and may mate with a drone from the same apiary or from a colony some distance from the apiary. The queen appears to mate as readily with the drones of one race as with those of her own. Queen bees will not mate within the hive. Any program to breed a better honey bee or to study the inheritance and expression of particular characters must include the use of some method to control the mating of the queen bee. This fact has been recognized for more than 150 years, and numerous attempts to control the mating have been made, but it is only comparatively recently that dependable control of the mating has been attained.

The first recorded attempt to control the mating of the queen was that of Reaumur (1740) who confined the queen and drones together in a glass dish. Such a procedure was a natural one to follow, since, at the time, it was assumed the queen mated within the hive. This latter point engaged the attention of Huber (1814) who by carefully controlled experiments performed 1787 to 1789 proved the queen mates outside the hive and will not mate when confined to the hive. At the suggestion of Charles Bonnet, Huber tried to inseminate virgin queens artificially by introducing semen from the drone into the vagina of the queen by means of a hair pencil. He reported the results as unsatisfactory.

Many attempts were made to control the mating of the queen during the succeeding century. Most of the workers, among whom were Cramer (1881), Davitte (1901), and Demaree (1881), endeavored to obtain matings by confining the queen and selected drones to enclosures of various kinds and sizes. Claims were made in some cases that matings took place, but these claims were not substantiated. Various other methods were tried without verified success, among which were: (1) tethering the queen by means of a fine thread attached to the thorax, Demaree (1881), Shuck (1882); (2) confining the queens and drones to the hives until evening when drones of other colonies were no longer flying, Kohler (1868); (3) squeezing fluid from drone larvae onto queen larvae, Lee (1884); and (4) by squeezing seminal fluids of the drone onto the vulva of the queen, McLain (1887).

While none of the above methods could be considered successful, isolated mating stations have been employed extensively in some countries with apparent satisfaction, Bruennich (1913), Heberle (1913). The isolated mating station was employed by the United States Department of Agriculture, Division of Bee Culture in their 1948 breeding program.

EARLY USE OF INSTRUMENTS.—The use of the syringe in the artificial insemination of queen bees was introduced by Nelson McLain in 1886 (McLain 1887). McLain reported success with this method and also by squeezing semen from the drone directly onto the vulva of the female. He also reported success in getting queens mated in a greenhouse.

Shafer (1917) after reviewing the literature pertaining to the controlled mating of queen bees or to the morphology of the queen and drone, attempted in 1916 to inseminate virgin queens by causing the copulatory organ of the drone to evert from the drone and into the sting chamber and bursa copulatrix of the queen. Since little was known about the process of insemination in nature Shafer began his experiments by studying the structure and functioning of the sex organs of the drone, and the position which the severed end of the penis occupied in the queen upon her return from the mating flight.

In his insemination attempts Shafer held the queen in the left hand and spread the genito-anal plates with forceps. A small thin plate was soldered to the lower edge of one prong of the forceps which fitted beneath the sting and pulled it dorsally as the sting chamber was opened. The forceps were mounted on the upper side of a triangular block which could be brought into the field of a dissecting microscope. The drone was held in the right hand in such a position the ventral sides of the queen and drone were facing the

same direction, and the penis of the drone was made to enter the bursa copulatrix of the queen by pressure applied to the drone's abdomen. In two cases the copulatory organ was torn from the drone and left in place in the queen. None of these attempts at insemination were successful.

Prior to 1915 Bishop (1920) attempted to inseminate queen bees both by the eversion of the penis of the drone into the queen, and by the injection of the semen with a syringe. Although none of these attempts were successful they brought about the realization that a more complete knowledge of the structure and functioning of the reproductive organs of both the queen and drone was essential to the development of a successful method of artificial insemination. Bishop undertook such a study and in 1920 published two excellent papers; one on the male sexual organs, and the other on the disposal of the sexual fluids in the organs of the female. He mentioned the valve-fold in the vagina of the queen and that it occluded the orifice of the median oviduct, but the significance of this fact appeared to escape him. Bishop came very close to developing a successful insemination technique and it is unfortunate he discontinued his efforts in this field.

In 1923 Charles W. Quinn (1923) who was engaged in the commercial production of queen bees, attempted to inseminate queens artificially for use in genetic studies. With the aid of his grandson, the writer, Quinn inseminated several queens which produced worker brood. The queens to be inseminated were held in the left hand and the sting chamber was opened with forceps in a manner similar to Shafer's technique. The drone was held in the right hand and faced in a direction opposite to that of the queen. The copulatory organ of the drone was made to enter into the sting chamber of the queen by pressure on the drone's abdomen. The organ was then cut from the drone and left in the queen.

These queens undoubtedly received only a slight insemination, but this was not known to Quinn. Six years later when the writer resumed work on the artificial insemination of queen bees at the Southern States Bee Culture Laboratory it was discovered that most of the queens treated by the Quinn-Laidlaw method received some degree of insemination but usually the insemination was slight. The search for the cause of these slight inseminations led the writer to make a study of the morphology and functioning of the reproductive organs of the queen and drone, and of the process of natural mating. This study confirmed Bishop's finding that the semen is deposited in the oviducts when the queen mates naturally, and indicated further that the semen cannot be injected into the oviducts in artificial insemination unless the valve-fold is held from over the orifice of the median oviduct during the injection. An account of this work is included in the Report for February 1933, United States Department of Agriculture Bureau of Entomology, Division of Bee Culture, Field Station at Baton Rouge, La.

THE DEVELOPMENT OF MODERN INSTRUMENTS.—It is generally accepted that the modern techniques of artificial insemination of queen bees began with Watson's demonstration of insemination in 1926. Watson's work was carefully done and other workers were able to obtain inseminations by his method. Watson (1927) used a microsyringe with thin straight walls for the injection of the semen into the vagina. The syringe was clamped in a Barber pipette manipulator attached to the stage of a dissecting microscope, and the queen was secured in a cradle fastened to the stage with rubber bands. The sting chamber was opened with forceps. Semen was obtained from the bulb of the partially everted penis of the drone.

Since 1926 there has been a slow but steady improvement in the instruments and technique of insemination.

The use of an anaesthetic.—The inseminations which were made before 1930 were performed without the use of an anaesthetic. The movements of the queen added to the difficulty of opening the sting chamber and injecting the semen into the reproductive tract. The writer, in considering the use of an anaesthetic to quiet and relax the queen, was advised by Jas. I. Hambleton to try carbon dioxide which had been used by the Bee Culture Division of the United States Department of Agriculture for some time to anaesthetize imported bees and queens for examination for *Acarapis woodi*. This suggestion was followed, and carbon dioxide was used with satisfaction from

1930 until 1934 when changes in the technique of introducing the semen into the queen seemed to make it desirable to find an anaesthetic having a more prolonged effect upon the queen. Numerous other materials were tried during that period and from 1934 to 1939 but none proved entirely satisfactory, Laidlaw (1932, 1944). However, the use of an anaesthetic became an integral part of the writer's technique in 1930 and from that time on all queens were inseminated with the aid of an anaesthetic. The use of an anaesthetic and the employment of carbon dioxide for this purpose was mentioned in the Report for May 1931, United States Department of Agriculture, Bureau of Entomology, Division of Bee Culture, Field Station at Baton Rouge, La.

Nolan (1932) also first used an anaesthetic in 1930. He used ether, but discontinued its use, and the use of all anaesthetics the same year.

Mackensen began using ether to anaesthetize the queens in 1939 and adopted the other essential features of the writer's technique. The operation of injection was easier than when no anaesthetic was used but the queens tended to lay several eggs in a cell, and Mackensen suspected the ether injured the queen. This conclusion had been reached earlier by the writer (1944). In 1944 Mackensen (1947) began the use of carbon dioxide, and in 1945 discovered that two treatments with carbon dioxide would stimulate the queen to begin oviposition promptly whether inseminated or not. This discovery was an important contribution to the technique of artificial insemination of queen bees, and recent instruments have included provisions for administering this gas to the queen.

The syringe.—Little is known of the syringes used in the insemination of queen bees prior to 1926. Watson (1927) designed and constructed a very efficient syringe for use with his method of insemination, and until 1948, his syringe, or some modification of it, was used by nearly all workers. Watson's syringe (Fig. 1) was constructed of glass with the plunger extending into the capillary tip. The plunger was moved by a screw mechanism. The tip was about 0.5 mm. in diameter and had thin straight walls. These syringes were very delicate and considerable skill was required for their construction.

Nolan (1937) in 1937 described a modified Watson syringe of more sturdy construction (Fig. 1). The glass barrel with its screw mechanism was replaced with the barrel and mechanism of a mechanical pencil. The plunger, made of No. 28 Nichrome wire, was cemented to the piece which had held the lead, and could therefore be protracted and retracted in the same way as the lead. The syringe tip, which had thin straight walls, was drawn from glass tubing to fit the plunger and had an outside diameter of 0.55 to 0.60 mm. The greater length of the tip was contained within the barrel of the pencil, but 1.5 to 2 inches was allowed to protrude beyond the barrel end. This syringe was relatively easy to construct and proved to be a valuable contribution to development of instruments for the artificial insemination of queen bees.

The writer (1944) in 1938 adopted Nolan's pencil-type syringe but modified the tip. The tip (Fig. 1) was drawn from thick wall tubing to fit a plunger smaller than Nolan's (No. 30 spring wire) which resulted in the tip having an outside diameter of about 0.9 mm. with a bore of about 0.27 mm. The end of the tip was ground to a cone shape. The vaginal orifice of the queen has a diameter of about 0.67 mm. The cone shape point could be inserted into the vagina, therefore, for about half its length and it fitted the orifice so tightly the semen could not escape on injection. This type of point is easy to insert into the vagina and injuries are reduced to a minimum. Mackensen in 1939 drew out the end of a Nolan-type syringe to a fine point which could be inserted into the median oviduct, and this type of syringe point is used by workers of the United States Department of Agriculture, Division of Bee Culture and by many other workers.

The above mentioned syringes were quite satisfactory but they all were rather fragile and the tips could not be removed to exchange for clean ones. In 1947 Roberts (1947) designed a syringe constructed largely of plastic which was fitted with a removable plastic tip having the point drawn out to a diameter of .012 inch so it could be inserted into the median oviduct (Fig. 1). The tip was practically unbreakable, but the plastic was

subject to wear and after extended use the bore of the tip became so large it was difficult to draw the semen up. Roberts later made this syringe of aluminum with only the tip of plastic.

The advantages of an unbreakable and exchangeable tip are very real, and the elimination of the plunger in the syringe tip would likewise eliminate the problem of wear. Three syringes incorporating at least two of these three features have recently been devised. Watson designed a syringe in 1947 which had a large sturdy glass barrel with a screw at one end, which extended into the barrel, and a Luer taper at the other (Fig. 1). The tip was drawn from glass tubing so that one end fitted the taper of the syringe barrel and the other end was drawn to a fine point. The syringe barrel was filled with water when in use, and by displacing the water with the screw and then reversing the action semen could be drawn up into the tip.

Watson *et al.*, (Park 1948), had collaborated earlier in designing a syringe which consisted of a glass barrel with a Luer taper at each end, and which had a tight fitting plunger. The tip was identical to that used by Watson in his later design. The plunger was moved by a mechanism which was graduated to take up a certain amount of semen with each turn of the screw.

Mackensen (1948) in 1947 designed and used a syringe which had no tight fitting plunger in either the tip or the barrel (Fig. 1). Semen was drawn into and expelled from the tip by the ingenious use of a replaceable rubber diaphragm fitted into the end of the syringe barrel. The plastic tip was similar to the one described by Roberts but had a cone-shaped cavity at the screw end. When the tip was screwed into the syringe barrel this cavity fitted tightly against the diaphragm which closed the bore of the tip at the screw end. The diaphram was pushed into the cone-shaped cavity of the tip with a plunger activated by a screw. When the action of the screw was reversed the diaphragm resumed its normal position drawing up the semen. In actual use the end of the syringe barrel was filled with water before the tip was screwed into the barrel. Then by turning the plunger screw and pushing the diaphragm into the cone-shaped cavity the water was expelled from the tip leaving only the bore filled with water which acted as a plunger in

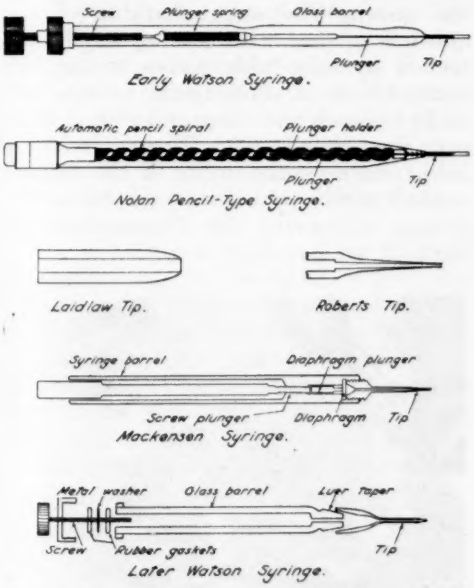

FIG. 1.—Types of microsyringes used in the artificial insemination of queenbees. (Roberts Tip redrawn from U.S.D.A., Manual for artificial insemination of queen bees. Mackensen syringe redrawn from Mackensen. Later Watson syringe redrawn from Rothenbuhler and Park.)

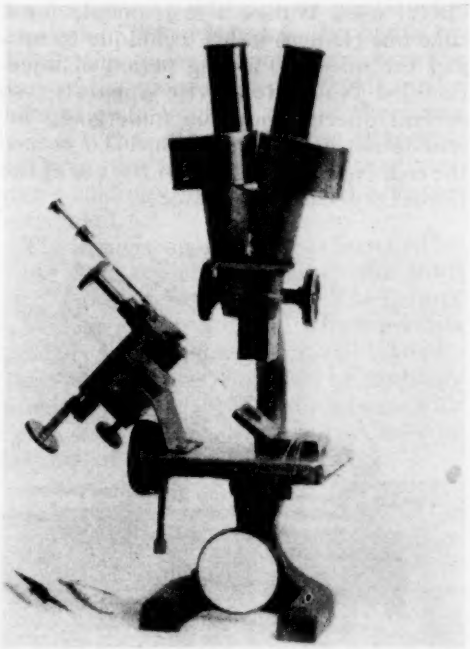

FIG. 2.—Syringe, syringe manipulator and cradle as used by Watson. (After Watson, Controlled mating of queen bees.)

the tip. By reversing the screw this water was partly withdrawn into the base of the tip leaving a small air space between the water and the point of the tip to prevent the dilution of the semen with water. Semen could be taken up by continuing the reverse action of the screw.

The queen manipulator and syringe manipulator.—Most workers before 1926 held the queen in the hand during the injection of the semen. Watson (1927) in 1926 tied the queen in a cradle which was secured to the miscroscope stage with rubber bands and separated the terminal sclerites of the abdomen with forceps held in the left hand. The syringe was clamped in a Barber pipette manipulator (Fig. 2), and could be moved in any direction with perfect control. Had not the valve fold interfered with the injection of the semen into the oviducts this apparatus would have been fairly satisfactory in the hands of a skilled operator. Watson's apparatus marked the beginning of the development of precision instruments for the artificial insemination of queen bees.

The most important advance in the design of instruments for the artificial insemination of queen bees in the period immediately following Watson's demonstration was made by Nolan. Nolan (1932) used Watson's instruments for a time but changes in his technique to subject the queen to a long period of injection led Nolan to devise apparatus so several queens could be undergoing insemination at the same time. To reduce the cost Nolan discontinued the use of the Barber pipette manipulator.

Nolan's manipulator consisted of a false stage which lay transversely across, but unattached to, the stage of a dissecting microscope and was fitted with a post at either end. The posts carried a bar between them which bore the queen confined in a glass tube with the terminal abdominal segments protruding. Each post was fitted above the bar with an adjustable wooden block having a hole through which the handle of a teasing needle was inserted. The tips of the teasing needles were bent to form hooks for opening the sting chamber of the queen. The syringe was held by an adjustable wooden block secured to the tip of the post on the right side. Movement of the syringe for insertion into the vagina was accomplished by sliding the syringe through the hole in the supporting block. This apparatus was quite satisfactory and has been used by the United States Department of Agriculture, Bee Culture Division and others since 1932.

Recently Mackensen & Roberts (Anonymous 1948), modified and refined this apparatus and constructed it of steel and alumnium (Fig. 3). Carbon dioxide is administered to the queen by means of rubber tubing extending from the carbon dioxide cylinder to the glass tube holding the queen. The sting chamber of the queen is opened with teasing needles attached by adjustable pieces to the two upright posts, and one needle is fashioned to fit beneath the sting and pull it from over the vaginal orifice. The valve-fold is held from over the orifice of the median oviduct with a probe while the end of the syringe is inserted into the median oviduct.

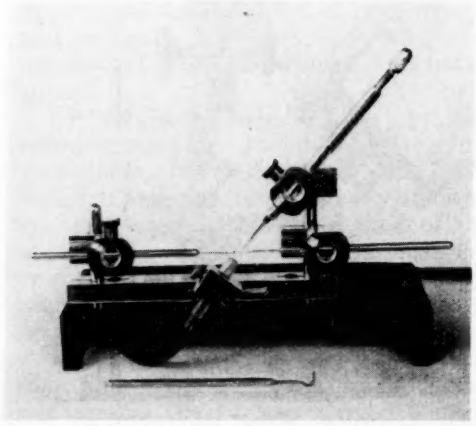

FIG. 3.—Roberts and Mackensen insemination apparatus. (Photograph courtesy of U.S.D.A.)

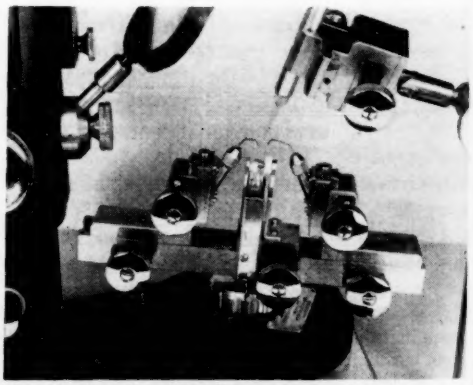

FIG. 4.—Details of Laidlaw queen and syringe manipulators, right side. (Mackensen syringe.)

The writer designed and used in 1938 an instrument for holding and opening the queen which permitted the operator's hands to be brought close to either side of the queen to perform the various insemination operations. The queen, after being anaesthetized, was clamped by the thorax, head down, between two upright pieces which were faced with sponge rubber. The dorsal and ventral hooks used in opening the sting chamber were attached to metal blocks which could be moved by screws up or down and toward or away from the queen. The dorsal hook was made to fit beneath the sting and pull it from over the vaginal orifice. The queen holder and manipulator was mounted by means of a ball and socket joint on a brass base which permitted the queen to be tilted to any desired angle. The entire apparatus could be moved in any direction in a horizontal plane on the stage of a dissecting microscope. The syringe was held by a spring clamp mounted on an adjustable arm and post rigidly attached to the microscope stage, and the clamp had sufficient tension to hold the syringe firmly but yet permit the syringe to be raised or lowered. Since the syringe could be moved only up or down during the operation, the queen was brought into proper position for insertion of the syringe into the vagina by moving the apparatus holding the queen. Ether was used as an anaesthetic at this time and no provision was made to subject the queen to a constant atmosphere of the anaesthetic. This apparatus proved to be very satisfactory aside from the crudeness of construction.

The advantages displayed by this instrument were: (1) the queen was easily secured in the desired position between the upright pieces and could be tilted to any desired angle, (2) the hooks for opening the sting chamber of the queen were movable in two directions by screws, and the dorsal hook held the sting pressed against the dorsal wall of the sting chamber and away from the vaginal orifice, (3) the queen could be moved at will after she was opened and could be set aside while the syringe was being filled with semen, and (4) the hands could be brought close to either side of the queen to lower the valve-fold and to perform other necessary operations. This apparatus is described in the First Quarterly Report, United States Department of Agriculture Bureau of Entomology and Plant Quarantine, Division of Bee Culture, North Central States Bee Culture Field Laboratory, April-June 1938.

In the spring of 1948 this apparatus was redesigned by the writer and was conconstructed commercially.[1] The new apparatus consists of two parts: the queen manipulator, and the syringe manipulator (Fig. 4). The queen manipulator weighs 1364 grams (or 3 lbs.), is 6 inches long and 3.25 inches high, of convenient size to fit on the stage of a dissecting microscope. It is constructed of brass with a chrome finish of all except the base which has a black finish. The queen holder is situated at the middle of the instrument and clamps the queen's thorax firmly while allowing the abdomen to extend above the holder. The carbon dioxide used as an anaesthetic is directed from either side toward the spiracles. The opening hooks are held by chucks fastened to pieces movable up or down and toward or away from the queen by means of racks and pinions. The queen can be tilted to any desired angle by means of the ball and socket joint. The manipulator holding the queen can be removed from the stage of the microscope while the syringe is being filled, and then the queen can be brought into proper position for insertion of the syringe into the vagina by sliding the queen manipulator over the stage of the microscope. The hands can be brought close to either side of the queen to lower the valve-fold or to otherwise assist in the operation. If desired, the queen-holding tube can be used with this instrument.

The syringe manipulator is fastened by a bar and adjustable rods to the front part of the microscope stage. The syringe is held firmly by a clamp which permits its ready removal and which will take any type syringe. The syringe can be smoothly raised or lowered by a sliding piece with a rack and pinion adjustment. A moving distance of 0.875 inch is provided.

A microscope lamp was used as a source of light with this latest apparatus, and the light was reflected into the sting chamber of the queen with a microscope mirror attached to the arm of the microscope. A cap fitted with plastic rod was devised by J. E. Eckert to fit over the lens of the

[1] By the firm of Silge and Kuhne of San Francisco which specializes in the construction of precision instruments.

lamp, which reduced the heat to a minimum without serious loss of light.

This apparatus was used throughout the 1948 season with complete satisfaction. The two manipulators are precision instruments and as such their cost together is about $350.00. They are durable and are built to give many years of service.

METHOD OF USING THE LAIDLAW MANIPULATORS.—In using these instruments the queen manipulator is set aside and the queen is anaesthetized with carbon dioxide while she is held in the hand or confined to a cage. She is then clamped by the thorax, head down, between the queen-holding upright pieces of the queen manipulator with her ventral side toward the operator, and a small stream of carbon dioxide is allowed to flow over the spiracles. When this has been done, the manipulator with the queen in position is brought to the stage of the dissecting microscope and the sting chamber of the queen is opened with forceps held in the operator's left hand. The dorsal hook is brought over the queen and lowered into the sting chamber and is adjusted to fit beneath the base of the sting and pull it dorsally from over the vaginal orifice. The ventral hook is next brought into place and adjusted. The queen manipulator with the queen is now set aside while the syringe is filled with semen.

The syringe is prepared for use and is clamped between the jaws of the syringe manipulator. Eversion of the copulatory organ, which is accompanied by ejaculation of the seminal fluids, is brought about in a selected drone by moderate pressure applied to the drone's abdomen. The eversion usually stops before the semen has been released to the exterior of the organ. Further pressure on the drone's abdomen will cause the organ to continue eversion with the release of the semen and accompanying mucus. The drone, with the everted organ and adhering fluids, is brought to the tip of the syringe and the semen is taken up into the syringe. If more than one drone is used this procedure is repeated until the desired amount of semen has been taken into the syringe.

After the syringe is filled it is raised so it will clear the queen, and the manipulator with the queen is again placed on the microscope stage with the ventral side of the queen toward the operator. The syringe is then lowered until the tip is within the sting chamber, and the queen manipulator is moved over the microscope stage so the point of the syringe is directly above the vaginal orifice. With a flattened probe the valve-fold is lifted from over the orifice of the median oviduct and is pushed ventrally within the vagina and held there while the point of the syringe is inserted into the vaginal opening. The valve-fold lifter is then removed and the point of the syringe is pressed firmly against the vaginal opening. The semen is injected into the oviducts by slowly turning the syringe screw which activates the plunger and forces the semen out of the syringe tip. When the injection is finished the syringe may be raised to a position above the queen and removed from the syringe manipulator.

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Determining Toxicity of Agricultural Chemicals to Honey Bees

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The term agricultural chemicals encompasses all chemicals which are used in farming operations and includes materials used as fertilizers, herbicides, fungicides, defoliants, and insecticides as well as many others. The number of such compounds has increased greatly within the past few years and the requests for information as to how each one affects plant or animal life have pyramided with the production of each new chemical. Numerous workers in all sections of the world are studying to supply answers to these requests and frequently the results are not as comparable as they could have been because of variations in the factors influencing the experiments, or because the methods employed are not described in sufficient detail.

The honey bee has been used as an experimental insect in many of the toxicity tests because it is one of our most beneficial economic insects. The honey bee is the principal insect agent in the pollination of a majority of our fruit, vegetable, seed and pasture crops and is becoming more important constantly because of the decimation of the solitary bees through the effects of poisoning, weed control, and intense cultivation of areas in which the solitary bees construct their nests. Consequently, it is essential to consider the welfare of the honey bee and of the beekeeping industry in all of the pest control programs using materials which are toxic to bees.

In determining the toxicity of various chemicals to bees, it would be of considerable value if the results of experiments were expressed in terms which would make it possible to compare one chemical with another. A review of current literture on this subject indicates that a wide variety of methods are used as well as different expressions to indicate the degree of toxicity. In one case a research worker may indicate that a certain chemical is not toxic to bees while other workers will show that it is highly toxic as a stomach poison and as a contact insecticide and may have considerable killing power as a fumigant. (This has happened in experiments with chlordan.) If one read only the conclusion in the first instance, one would be given a false sense of security in using the chemical when the safety of honey bees is concerned.

Results are sometimes expressed in terms of parts per million, or in p.p.m. of the body weight of the insect, or in micrograms of the toxic element required to kill a bee, or in the amount required for a median lethal dose to kill 50 per cent of the experimental insects within a stated period of time. Sometimes laboratory temperatures are used and again the insects are placed in control cabinets in which both the temperature and the humidity are controlled. Sometimes the bees are fed individually or in groups or fed individually and then transferred to common cages. Each method involves

variable factors which influence the results.

Another variable commonly included is that of the solvents used in makiug up specific solutions. For example, alcohol, acetone, and different oils have been used in making solutions of the hydrocarbons from which suspensions or emulsions are made. The percentage of sugar used in the solution needed for feeding bees is still another factor which may influence the results. The relation of each solvent to the honeybee should be stated in order to evaluate correctly the effect of the chemical itself. Sometimes a solvent can mask or reduce the effect of a chemical so that the results are not comparable with the results secured in the use of other solvents. For example, the toxicity of a chemical may vary considerably if used in a suspension and as an emulsion. Since both suspensions and emulsions are used in commercial practice, experimental results with both are of value.

It is easier to secure information on the apparent toxicity of a chemical when it is used as a stomach poison than when it is used in the form of a contact insecticide or as a fumigant. One can feed exact amounts of a chemical to bees but it is difficult to measure the amounts necessary to induce a toxic effect either on contact or as a fumigant. Again, how can one measure the contact effect of a chemical when it is used as a stomach poison?

FIELD OBSERVATIONS.—Observations on the effects of various chemicals on bees when sprays or dusts or vapors are applied to crops are subject to still greater variations than when laboratory methods are used. One can not control the flight of bees and it is extremely difficult to determine what percentage of field bees from a particular colony is working in the treated areas. Bees may work at a distance of a mile or more from where their hives are located and have been poisoned when located as far as 5 miles from tomato fields to which calcium arsenate had been applied by airplane. Consequently, it may be entirely wrong to conclude that a chemical is not toxic to bees under field conditions when no appreciable injury can be determined to colonies located adjacent to fields treated with a given chemical. Some chemicals affect brood adult bees while other poisons may affect only the field force.

For the above reasons, it would be of value for each research worker to describe in detail the methods used in each experiment and the environmental conditions which may affect the results. Repetition can be avoided by referring to previous descriptions of methods used.

THE VALUE OF LABORATORY RESULTS VS. FIELD OBSERVATIONS.—When bees are confined to cages in the laboratory and are fed various concentrations of a chemical, one may secure results which may or may not indicate the probable toxicity of the chemical under field conditions. For example, DDT has been found to be highly toxic to bees as a contact insecticide and also as a stomach poison, and yet when DDT is substituted for calcium arsenate in the control of various insects, the formerly heavy loss of bees from arsenical poisoning is reduced to a point where no appreciable injury is observed or where only the field force is partially or entirely destroyed. *DDT is not sufficiently repellent to bees to prevent injury* to them when they work among newly dusted plants; so repellency cannot be the reason for this seeming disparity in results. DDT is less toxic at temperatures above 90° F. than it is in the lower ranges, but this problem is of no great significance because dusts are generally applied early in the morning, or late in the evening or at night when the air is cool and convection currents interfere less with depositing the materials on the plants. The amount of DDT needed per acre to control most field and orchard insects is considerably smaller than for the arsenicals. DDT is also highly insoluble in water or nectars so the chemical probably affects the pollen and nectar gatherers primarily through their contact with the dusts. DDT so affects bees that they soon become abnormal in behavior and cease to collect pollen or nectar, and become lost or die, resulting in the storage in the combs of insignificant amounts of pollen contaminated with the chemical.

Laboratory results, therefore, may indicate merely the effects of a chemical on bees should they secure in the field the same amounts of the chemical which can be shown to be injurious in the laboratory. Laboratory results may point to the need for extreme care in the use of certain chemicals on plants in bloom or at times when pollinators are most active,

as well as the amounts which may prove injurious to bees if the materials are applied to plants visited by bees for either pollen or nectar. Laboratory results may also show where one chemical may be used with greater safety to bees than other more toxic chemicals.

METHODS USED IN DETERMINING THE TOXICITY TO HONEY BEES OF DDT, DDD, TOXAPHENE, CHLORDAN, PARATHION, BENZENE HEXACHLORIDE AND OTHERS.[1]—In determining the toxicity of these chemicals to bees when fed to them in sugar sirup, solutions were made in 95 per cent alcohol by dissolving a known weight of a material in a given amount of alcohol at laboratory temperature, which varied between 70 and 85 degrees. Then specific amounts of these stock solutions were added to definite amounts of a 20 per cent sugar sirup. This resulted in a suspension of extremely fine particles in all of the hydrocarbons and a solution of parathion. (Acetone was used as a solvent for chlordan instead of 95 per cent alcohol.) The probable toxic range of a chemical was determined by feeding different concentrations to from 30 to 50 bees in 4 by 5 by 0.75 inch cages. (See fig. 1.) The solutions were fed from inverted vials which were closed with paraffined paper perforated with a small hole. After the probable toxic range was determined other bees were placed in individual queen mailing cages and fed specific amounts of the suspensions by means of micropipettes arranged in a holder as illustrated in figure 1. By varying the amounts fed from .005 to .03 ml., as well as by varying the concentrations of the chemicals, one can have a wide range in the specific amounts of the toxic substances ingested by the bees. Soon after the bees were fed individually, each was provided with 20 per cent sugar sirup in a wax cell cup with which each cage was provided. The bees were then held either at room temperature, which were maintained at a minimum of 70°, or were placed in a control cabinet where the temperature and humidity could be kept nearly constant.

The bees were taken from the top story of a strong colony and those placed in individual cages were selected so as to be of medium age, neither old nor too young. Check lots of bees fed on 20 per cent sugar sirup containing the same percentage of the solvent were run to indicate the normal death rate as well as the probable effect of the solvent on the bees. Observations were made at frequent intervals during the first few hours after the bees were fed and then at 8 to 12 hour intervals thereafter, over a period of from 3 days to a week. If the effects of a chemical are limited to 48 or 72 hours, the percentage of error due to death from natural causes is negligible. Although such a limited period of time does not take care of the prolonged effects of a poison, most injuries proved fatal to bees within a 72-hour period.

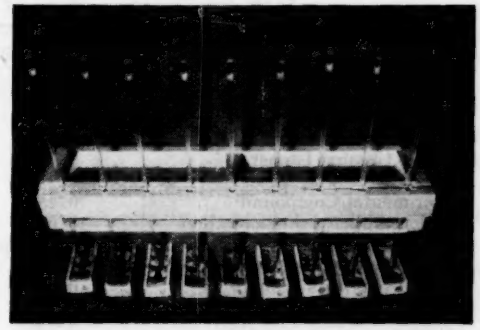

FIG. 1.—Illustrating the method used in feeding bees in individual cages by means of a battery of micropipettes.

In some cases poisons were added to pollen paste which was then fed to nuclei to determine the apparent effect on the nurse bees and brood.

Contact reactions may be determined in different ways. Caged bees may be dusted or sprayed with the chemical and then fed sugar sirup. It is difficult to determine the exact amounts of the chemical in such instances but if the percentages of the chemicals and the methods of application are standardized, the toxicity of one chemical may be compared to that of another. Or standard sized cages can be sprayed with similar concentrations of different chemicals and the results of exposure over different periods of time can be compared. Definite amounts of a chemical may be deposited on glass or paraffined paper and the results of causing bees to walk on the treated surfaces observed over varying periods of time. In this method, the bees may be in contact with the glass for only a part of the time as they may walk on the top or

[1] Including the product "118" made by Julius Hyman Co.

Table 1.—The toxic effects of certain chemicals on honey bees.

CHEMICAL	L/D-50 IN 72 HRS. MMG. PER BEE	STOMACH POISON TIME IN HRS.	CONTACT POISON IN HRS.	FUMIGANT ACTION IN HRS.
Benzene hexachloride (90% Gamma Isomer)	0.15	3– 24	0.1–0.5	0.5–1.5
Chlordan	1.21	5– 24	0.1–0.5	1.5
Experimental Compound[1]	0.25	6–144	1.0–2.0	4.0
Dichlorodiphenyl dichloroethane	16.0	2– 72	2.0	0
	4.6 (room temp.)	1– 48		
DDT	12.0+(95°F.)	5–120	5+	0
Hexaethyl tetraphosphate	0.29	2– 24	1–48	
Parathion	0.07	1– 24	0.5	3–6
Tetraethyl pyrophosphate	0.75	1– 24	0.5	
Toxaphene	22.0	5– 24	1–3	0

[1] "J.H. 118", a close relative of chlordan, was manufactured by the Julius Hyman Co. of Denver, Colorado. Its use was still in the experimental stage.

sides of their cages as well as on the plates. The fumigating effects of a chemical may also be difficult to distinguish from the contact reactions.

The fumigant action of chemicals may be compared by the use of caged bees placed above plates or areas on which quantities of the chemical have been applied. Or, caged bees may be placed in a room or box whose walls have been sprayed with the material. Since bees spend considerable time in close contact with the blossoms and to some extent crawl over the blossoms and adjacent leaves in collecting nectar and pollen, it is of value to observe the amount of time necessary to produce abnormal activities of bees through the contact or fumigant action of a chemical. Chemicals which affect the caged bees through contact or fumigant action within a matter of 15 minutes can be expected to reduce the field force of a colony within a short time if the chemicals are applied in similar concentrations to plants on which bees are working. Pronounced reductions in colony strength may also be affected with poisons which adversely affect bees over a longer period of time because of the cumulative effects during several trips of the bees to the field.

Finally, observations were made on the activities of bees visiting sprayed or dusted plants. Some bees were captured and held in cages to determine their reactions in contrast to bees taken directly from hives and held in similar cages. The population strengths of colonies were observed as well as the condition of the brood when bees were placed in an area immediately before a crop was to be treated, and soon after the applications were made. Beekeepers were also requested to report instances of damage by chemical poisoning and to secure all information pertaining thereto. Such reports were checked whenever possible.

RESULTS OBTAINED IN TESTS OF THE TOXICITY OF DIFFERENT INSECTICIDES.—The results of feeding bees in individual cages known quantities of different chemicals in 20 per cent sugar sirup are listed in table 1. After the bees were fed from micropipettes, they were held in individual cages supplied with 20 per cent sugar sirup and kept at a temperature which generally ranged between 70 and 85° F. In other tests, bees fed varying amounts of chemicals were placed in a cabinet of 29.3 cubic feet capacity in which the temperature of 95° F. was maintained with a high humidity. Only in the case of DDT did it appear that the high temperature appreciably affected the toxicity of the chemical to bees. The results of exposing bees to the contact and fumigant effects of the chemicals are also given.

DISCUSSION.—An attempt has been made to assemble in the above table comparative data on the toxic effect of various insecticides on honey bees when conducted in similar manner in the laboratory. The L/D-50 for the different chemicals were determined by feeding caged bees known quantities of each material in 20 per cent sugar sirup as described earlier in this article. The time it took for the bees to die is expressed in the third column and shows a wide variation between the individual bees in the various tests and within the different tests involving any one chemical. The contact

and fumigant effects were generally of shorter durations. In all three categories, however, the bees became abnormal in much shorter periods than those indicated and in most cases would have died earlier without the protection of the cages.

Under field conditions, observations have indicated that dichlorodiphenyl dichloroethane caused no appreciable injury to the population of colonies and DDT has been injurious to the field force of colonies only when used on alfalfa in full bloom. Reports from Utah and elsewhere indicate that 10 per cent DDT dusts on alfalfa are more injurious to bees than 5 per cent or lower concentrations. In no case have our observations or reports from beekeepers indicated the loss of any entire colony from DDT. Chlordan dusts have reduced the field force of colonies by from 50 to 80 per cent when applied to alfalfa in bloom. Chlordan in oil (2.5 per cent solution) caused the loss of brood and a portion of the bees when applied in hot weather as an oil spray to grass, in front of 30 colonies. A quick removal of the affected colonies prevented much heavier losses. The bees apparently pulled the fumes through the hives by their ventilating operations.

Toxaphene, dichlorodiphenyl dichloroethane and DDT would appear to be relatively safe chemicals when used in minimum quantities of 1.5 pounds per acre, especially if applied when bees are not flying and when plants are not in bloom. The destructiveness to bees of the other chemicals listed in the above table may depend on the concentrations used as well as on the time of application.

None of these chemicals listed was repellent to bees in suspensions or solutions and none have sufficient repellency to prevent the loss of bees when applied as a dust.

The reduction in the field population of a colony may not be detected unless the colony is examined before poisons are applied and again within the week following lack of the effectiveness of colonies as pollinators or as honey producers results when the field force is decimated by poisons.

Tests to Control Horn Flies with New Insecticides

GAINES W. EDDY and C. H. GRAHAM, *U.S.D.A., Agr. Res. Adm. Bureau of Entomology and Plant Quarantine*

In the summer of 1947 tests were conducted at the Kerrville, Texas, laboratory of the Bureau of Entomology and Plant Quarantine to compare the effectiveness of some of the more recently developed chlorinated hydrocarbon insecticides against horn flies, *Siphona irritans* (L.).

The speed with which DDT, the methoxy analog of DDT, (1,1-dichloro-2 2-bis(p-chlorophenyl) ethane), chlordan, and chlorinated camphene knocked down flies was determined in small-cage tests and in large-cage tests whereby flies were liberated on animals treated with these materials. Wettable-powder and emulsion formulations of DDT were compared in several tests. The results of the knock-down tests, together with the duration of effectiveness of the different insecticides when applied on Jerseys and of DDT when applied to Herefords, Jerseys and Brahmans, are given in this paper.

SPEED OF KNOCK-DOWN.—*Small-Cage Tests.*—In laboratory tests to determine the speed with which flies are knocked down, screen-wire cages 3.5 inches in diameter and 8 inches high were dipped in preparations containing 0.5 per cent of the test material. One cage was treated with each preparation, and 20 flies were introduced into each cage 24 hours, 3 weeks, or 2 months after the cages had been dipped. The flies used in the tests were taken from the stock colony. They were considered knocked down when they were no longer able to maintain themselves on the side of the cage. During the tests the cages were stored indoors. The results of these tests are shown in table 1.

The methoxychlor acted more rapidly than any of the other materials. The cage treated with methoxychlor was almost as effective after 2 months' exposure as it was after the first 24 hours. The DDT wettable-powder preparation caused complete knock-down of flies in 8 minutes after 24 hours, but required 62 minutes after 2 months' exposure. Dichlorodiphenyl dichloroethane was fairly rapid in action, but not so fast

Table 1.—Time required to knock down all horn flies placed inside cages at different intervals after being treated with preparations containing 0.5 per cent of various insecticides.

INSECTICIDE	AFTER 24 HOURS	AFTER 3 WEEKS	AFTER 2 MONTHS
Methoxychlor			
Wettable powder	5 min.	9 min.	12 min.
Emulsion concentrate	5 min.	13 min.	11 min.
DDT:			
Wettable powder	8 min.	18 min.	1 hr. 2 min.
Emulsion concentrate	14 min.	26 min.	1 hr. 18 min.
Dichlorodiphenyl dichloroethane wettable powder	17 min.	1 hr. 18 min.	2 hr. 32 min.
Chlordan, wettable powder	53 min.	3 hr. 25 min.	6 to 12 hours
Toxaphene wettable powder	73 min.	2 hr. 52 min.	4 hr. 8 min.

as DDT or methoxychlor. Chlordan and chlorinated camphene were found to be considerably slower than dichlorodiphenyl dichloroethane. After 24 hours chlordan caused complete knock-down of flies in 53 minutes and toxaphene in 73 minutes, whereas in the tests made after 3 weeks and after 2 months chlordan required a greater length of time to cause knock-down than did chlorinated camphene.

The fact that the cage treated with methoxychlor retained its effectiveness even longer than the cage treated with DDT was of interest, because in the tests on animals the methoxychlor appeared to lose its effectiveness more rapidly than DDT. Methoxychlor might prove more effective than DDT when used as a spray inside of buildings. More information on this point is needed.

Large-Cage Tests with Animals.—In the first semifield tests observations were made on the knock-down of flies liberated on treated animals. Yearling Jerseys were sprayed with preparations containing 0.5 per cent of the various insecticides. Two animals were saturated with each material. After 24 hours the animals were placed inside individual screen cages together with 100 from the stock colony files. The time required to cause complete knock-down of the flies averaged 26 minutes for methoxychlor, 31 for DDT, 34 for dichlorodiphenyl dichloroethane, 44 for chlordan, and 90 minutes for chlorinated camphene. Except for chlordan, all materials required more time to cause knock-down of flies in these tests than in the small-cage tests. However , the order in which the materials caused knock-down was the same in both series. Many of the flies liberated on the animals treated with the methoxychlor and DDT were affected within 15 minutes. A similar action was shown by dichlorodiphenyl dichloroethane but not by chlordan or chlorinated camphene. None of the materials appeared to act as repellents. In fact, some of the flies on the animals treated with chlordan died while they were still attempting to feed.

One week after the animals had been sprayed, DDT caused knock-down in approximately 4 hours, whereas almost 6 hours were required for the other materials. Two weeks after treatment DDT was the only material that caused complete knock-down or kill in 24 hours; however, complete knock-down was caused by chlordan and toxaphene after 48 hours. Incomplete knock-down or kill was recorded for methoxychlor and dichlorodiphenyl dichloroethane after 48 hours.

DURATION OF EFFECTIVENESS.—Four semi-field experiments were conducted to determine the duration of effectiveness of the different insecticides as horn fly treatments. The animals were selected as to breed, length of hair, and size insofar as was possible. The materials were applied with a wheelbarrow power sprayer with fan-type nozzles operating at a pressure of approximately 100 pounds per square inch. Each animal was completely saturated with the spray material. At weekly intervals the treated animals were placed in individual screen cages and 100 flies from the colony were liberated in each cage All the flies went immediately to the animals. Mortality records were taken after 24 hours.

The first experiment was not started until July and the last ended in October

however, the results of the different tests have been assembled for convenience in table 2.

COMPARISON OF DIFFERENT INSECTICIDES (*Experiment I*).—The effectiveness of the different insecticides was compared by spraying yearling Jerseys with 0.5 per cent wettable-powder formulations and with emulsions of DDT and methoxychlor at the same concentration. One animal was sprayed with each preparation. However, 48 hours later the test was repeated on a second group of similar animals. The results of the two tests were combined.

All the materials caused complete mortality of flies at the end of the first week, but only the DDT-wettable-powder formulation gave 100 per cent kill after 2 weeks. After 3 weeks chlorinated camphene gave about the same results as did DDT. The other materials appeared to be definitely inferior. The methoxychlor caused a slightly greater kill than did dichlorodiphenyl dichloroethane or chlor-

Table 2.—Duration of effectiveness of some new insecticides against horn flies exposed in cages containing cattle treated with different insecticide formulations.[1]

PREPARATION	BREED OF CATTLE	PER CENT MORTALITY IN 24 HOURS OF FLIES LIBERATED AT INDICATED INTERVAL AFTER SPRAYING			
		1 Week	2 Weeks	3 Weeks	4 Weeks
Experiment I (Concentration 0.5 per cent)					
Wettable powders:					
DDT	Jersey	100	100	78.5	
Methoxychlor	Jersey	100	95.5	54.5	
Chlordan	Jersey	100	94	43.5	
Toxaphene	Jersey	100	98.5	80	
Dichlorodiphenyl dichloroethane	Jersey	100	88	47.5	
Emulsions:					
DDT-xylene[2]	Jerse	100	81	25.5	
Methoxychlor[3]	Jersey	100	82.5	29.5	
Check (untreated)	Jersey	—	7	9	
Experiment II (Concentration 0.5 per cent)					
Wettable powders, DDT	Hereford	100	100	94	
	Hereford	100	100	90	
Emulsions:					
DDT-xylene[2]	Hereford	100	99	48	
DDT-xylene[4]	Hereford	100	100	94	
DDT-toluene[3]	Hereford	100	100	94	
DDT-toluene[5]	Hereford	100	100	80	
Check (untreated)	Jersey	15	—	12	
Experiment III (Concentration 0.25 per cent)					
Wettable powder, DDT	Hereford	100	100	—	
	Jersey	100	67	—	
	Brahman	100	81	—	
Emulsion, DDT-xylene[4]	Hereford	100	92	—	
	Jersey	100	75	—	
	Brahman	100	74	—	
Check (untreated)	Jersey	6	13	—	
Experiment IV (Concentration as indicated)					
Wettable powders, DDT:					
0.25 per cent	Jersey	—	100	98	51
0.50 per cent	Jersey	—	100	100	59
1.50 per cent	Jersey	—	100	100	94
Emulsions, DDT-xylene:[4]					
0.25 per cent	Jersey	—	98	84	26
0.50 per cent	Jersey	—	100	98	55
1.50 per cent	Jersey	—	100	100	68
Check (untreated)	Jersey	—	14	—	5

[1] In experiment I two animals and in all other experiments one animal sprayed with each material.
[2] Commercial concentrate formulated for military use according to following specification: DDT 25%, xylene 65%, *Triton X-100* (mono-iso-octyl polyethylene glycol ether) 10%.
[3] Commercial preparation.
[4] Same formula as described in footnote 2 but prepared in the laboratory.
[5] Same formula as described in footnote 2 but prepared in the laboratory and containing toluene instead of xylene.

dan. The emulsions of DDT and the methoxychlor were less effective than the wettable powders of these materials.

COMPARISON OF WETTABLE-POWDER AND EMULSION FORMULATIONS OF DDT (*Experiment II*).—A further comparison of wettable-powder formulations and emulsions of DDT at 0.5 per cent concentration was made on Herefords. The toluene emulsion prepared in the laboratory appeared less effective than the other emulsions or the wettable-powder formulations. The xylene emulsion prepared for military use was even less effective than the laboratory-prepared toluene emulsion.

COMPARISON OF RESIDUAL EFFECT OF DDT ON THREE BREEDS OF CATTLE (*Experiment III*).—A Hereford, a Jersey, and a Brahman cow were sprayed with a 0.25 per cent DDT wettable-powder preparation, and a similar group of animals were sprayed with a DDT-xylene emulsion at the same concentration. Both preparations caused complete mortality of flies on all three breeds after one week. However, only on the Hereford sprayed with the wettable-powder formulation was the kill of flies complete in 24 hours two weeks after treatment. The mortality of flies on the Hereford sprayed with the DDT emulsion was 92 per cent. The wettable powders applied to Jerseys and Brahmans caused only 67 and 81 per cent kill. These results indicate that DDT will give better protection on Herefords than on Jerseys or Brahmans.

COMPARISON OF DDT-FORMULATIONS AT DIFFERENT CONCENTRATIONS (*Experiment IV*).—This test was conducted fairly late in the horn fly season (September 24 to October 24). The cooler weather at this time may account for the fact that certain concentrations gave better protection over a longer period than earlier in the season. Yearling Jerseys were sprayed with wettable-powder formulations and xylene emulsions containing 0.25, 0.5, and 1.5 per cent of DDT, one animal being used for each concentration. Two weeks after the treatment all formulations except the 0.25 per cent emulsion caused 100 per cent mortality of flies in 24 hours. After 3 weeks only the 0.5 and 1.5 per cent wettable-powder formulations and the 1.5 per cent emulsion caused complete mortality of flies. None of the preparations caused complete kill after 4 weeks. However, the 1.5 per cent wettable-powder formulation caused 94 per cent kill as compared with only 26 per cent for the 0.25 per cent emulsion. All three emulsions proved less effective than the wettable-powder formulations, although the difference was not great.

SUMMARY.—In laboratory knock-down tests against the horn fly, *Siphona irritans* (L.), small screen-wire cages were dipped in preparations containing 0.5 per cent of different chlorinated hydrocarbon insecticides. The methoxychlor caused complete knock-down in 5 minutes, DDT in 8, dichlorodiphenyl dichloroethane in 17, chlordan in 53, and toxaphene in 73 minutes in tests made 24 hours after the cages had been dipped. After 2 months' exposure the methoxychlor, DDT dichlorodiphenyl dichloroethane, toxaphene and chlordan caused complete knock-down of flies in 12, 62, 152, 248, and 360 to 720 minutes, respectively. The cage treated with methoxychlor apparently lost little of its effectiveness. The knock-down of flies exposed to animals treated with the insecticides was the same as that determined in the laboratory, except that a longer time was required.

In semi-field tests best results were obtained with DDT and toxaphene. In most of the tests wettable powders proved superior to emulsions regardless of the concentration of insecticide tested. DDT was more effective at 1.5 per cent concentration than at 0.5 or 0.25 per cent. The 0.5 per cent concentration gave only slightly better results than 0.25 per cent. In comparative tests with different breeds of cattle, DDT retained its effectiveness much better on Herefords than on Jerseys or Brahmans. The difference between the Jerseys and Brahmans was not great.

Donald L. Schuder, Purdue University graduate and graduate student, has been appointed assistant in entomology in the Purdue Agricultural Experiment Station. He will give special study to nursery insects.

Biology of the Major Species of Horse Flies of Central New York

H. Tashiro and H. H. Schwardt, *Cornell University, Ithaca, New York*

The data presented in this paper represent a continuation of the general study on the biology and control of horse flies in New York. Logothetis & Schwardt (1948) reported on the larval and adult biologies of *Tabanus lasiopthalmus* Macquart and *T. quinquevittatus* Wiedemann,[1] the common "green head." The first successful rearing procedures for the genus *Chrysops* and specifically for *Chrysops vittata* Wiedemann are also given by them.

Work of the 1948 season was conducted primarily on species of the genus *Tabanus* which are more of a problem on dairy animals than are species of *Chrysops*, or deer flies. Observations indicated that deer flies, while present throughout the summer, are of relatively little importance on dairy animals. The data contained herein are the results of one season's work on which investigations are to be continued.

Seasonal Distribution of Adults of Major Species.—The three major species in the central New York area were: *Tabanus lasiopthalmus*, *T. quinquevittatus*, and *T. sulcifrons* Macquart, the autumn horse fly. *Tabanus lasiopthalmus* was seen during the first week of June several days after initial emergence, reached its peak during the following week, and by the first week of July was practically gone. *T. quinquevittatus* replaced the former in importance in early July. This species was, by far, the most important and abundant species as well as the one having the longest season. *T. sulcifrons* did not appear until the first week of August. It is a large fly and because of its relative abundance was of major importance. *T. lineola* Fabr. together with its variety *T. scutellaris* Walker was present during a large part of the season but its numbers were small. *T. pumilus* Macquart, while its population was relatively high for a short time was, like *T. lineola* and its variety, a minor problem when compared to *T. lasiopthalmus*, *T. quiquevittatus*, and *T. sulcifrons*.

It is of interest to note that the rise in population was extremely rapid for the three major species with a peak of very short duration and with the population diminishing over a considerably longer period.

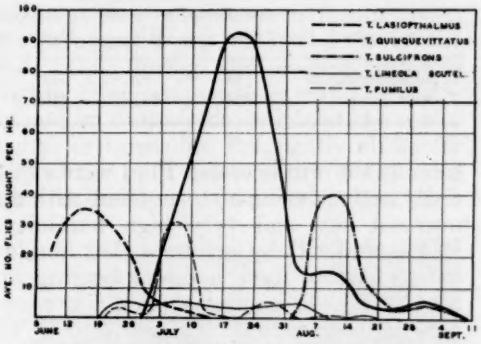

Fig. 1.—Seasonal distribution of adults of major species.

Information on seasonal abundance was gathered by catching flies from a tethered cow with a net modified for continuous sweeping. A celluloid cone was sewn inside an ordinary sweeping net. A half-inch opening was cut in the apex of the cone so that flies swept into the net and subsequently through the opening would be trapped between the cone and the closed end of the net. The end of the net was cut open and a drawstring sewn in. By releasing the drawstring the flies could be removed through a 5 or 6 inch opening.

Sweeping with such a net (fig. 2) could be continuous without having to remove the flies. Very few flies escaped since those missed would circle around the cow a few minutes and return to feed.

Effects of Daily Weather Conditions on Fly Activity.—At temperatures below 72° F. fly activity was practically negligible, but between 72 and the high 80's activity was usually heavy regardless of humidity conditions. In all cases with temperatures in the 90's fly activity seemed to be somewhat retarded. When temperatures were sufficiently high for flies to be active, wind movement appeared to affect activity more than any other factor. Large populations of flies on an animal always disappeared quickly with a gust of wind but reappeared as

[1] Until recently this species has been known as *Tabanus vicarius* Walker, 1848, but as Philip has recently shown (The American Midland Naturalist 37: (2): 313. *T. quinquevittatus* Wiedemann, 1821, is the correct name.

Table 1.—The average amount of blood consumed by a single fly of *Tabanus quinquevittatus* and *T. sulcifrons*. Weights in milligrams. Specific gravity of cow's blood—1.043. Ithaca, New York. 1948.

Species	Wt. Engorged			Wt. Unfed			Ave. Wt. of Blood Meal	Equivalent Value in cc.
	Max.	Min.	Mean	Max.	Min.	Mean		
T. quinquevittatus	154	85	126	73	35	55	71	.074
T. sulcifrons	774	451	592	322	187	248	344	.359

soon as the wind ceased. Flies were especially active during a storm front with an overcast sky and very high humidity. It was under these extremes that humidity seemed to have a direct bearing on fly activity. In a series of humidity readings at a constant temperature of 81 degrees the number of flies caught per hour at 57, 72, and 87 per cent relative humidity were 126, 132, and 258, respectively.

Extent of Blood Loss by Feeding Activities of Flies.—Unfed flies as well as full engorged flies were weighed to determine the mean weights of flies and amount of blood taken by individuals. The time required for a fly to engorge herself completely whether it was a small or a large species varied according to the location of the bite, those apparently near larger veins finishing sooner. Flies were able to engorge fully in as short a time as a minute and a half but the average time required was around 5 minutes. Some flies, however, took as long as 20 minutes to engorge and made several punctures before finishing. They feed to such an extent that they must excrete clear urine while feeding and continue to feed until some of the freshly engorged blood appears to be excreted.

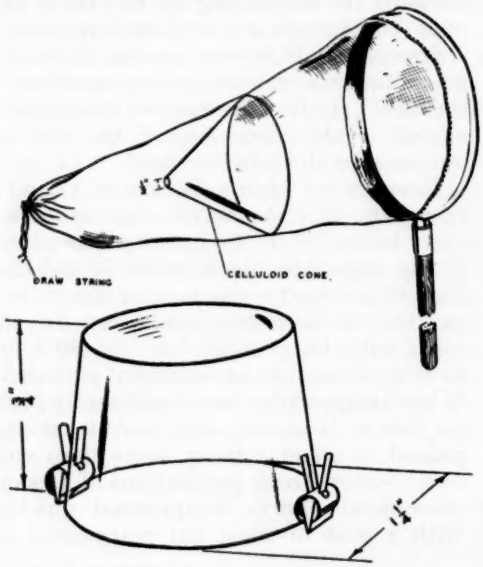

Fig. 2.—Modified net for continuous sweeping and celluloid cage to confine engorging flies on cows.

In catching engorged flies a celluloid cage, figure 2, was placed over the fly after she had started feeding and the cage clipped to the cow's hair. When fully engorged as evidenced by their attempts to escape flies could be removed immediately for weighing or left undisturbed for several minutes. By the use of 3 or 4 of these cages it was possible to be weighing flies and have several feeding in capivity at any one time. If it was desired to keep fully engorged flies for subsequent cage oviposition they were anesthetized with ether; otherwise, they were dropped into a strong cyanide jar prior to weighing.

Taking fully engorged flies from the field to the laboratory for weighing proved to be inadvisable since assimilation of the blood was very rapid. Within a period of 2 hours nearly half of a blood meal would be assimilated with simultaneous excretion of clear urine. Later in the season the balance was taken directly to the field and the flies weighed within a minute or two after removal from the animal. Table 1 indicates the amount of blood taken by single flies of two of the major species as determined by weighing individual flies in the field.

When flies were numerous it was not uncommon for 90 individuals of *Tabanus quinquevittatus* to engorge on a single animal per hour 8 or 9 hours a day. The 720 flies involved during an 8-hour period would, therefore, take 720×0.74 or 53 cc. of blood: With *T. sulcifrons*, a much larger fly, the losses were considerably more. With an average of 40 flies feeding

per hour for the same period of the day 320 flies would take a mean volume of 320×.359 or 115 cc. of blood. The total loss per animal may conceivably be much greater than these figures indicate since this does not include blood that drips or oozes from the wound after the flies leave, nor do these figures indicate the activities of all species involved at any one time. It is probable that these estimates of blood losses can be doubled. Webb & Wells (1924) estimated that 20 to 30 flies of *T. phaenops* O.S., feeding for 6 hours, take 100 cc. of blood per day per animal. Philip (1931) estimates that blood loss per day per animal could be 300 cc. When populations as high as 250 flies feed on one animal for any length of time losses may mount up very rapidly. At times an animal could be observed after a heavy outbreak of flies with its neck, the area which appears especially vulnerable to attack, completely covered over with dried blood, and one's palm could not be placed on any part of the animal's body without touching blood. Under such conditions an animal may just stand passively and no longer fight the flies.

LARVAL COLLECTIONS.—The work of Logothetis & Schwardt (1948) in finding larvae of *Tabanus quinquevittatus* in pasture sod prompted further investigations along this line. They dried sod over a screen wire and caught the larvae as they fell to a pan of water below. This same principle was used in constructing an apparatus for collecting larvae from sod.

A horizontal wooden frame measuring 6 by 12 feet and divided into eight 3 by 3 foot squares was made with 2 by 4 lumber and supported by legs 3.5 feet high. The entire upper surface of the frame was covered with wire screen having half-inch mesh and each 3 by 3 foot square was partitioned off with 1 by 4 lumber placed on edge. Eight sheet metal funnels, with an opening of 3 by 3 feet which tapered to a 6-inch opening, were nailed to the underside of each 3 by 3 square so that any object falling through the wire screen would be concentrated to fall through the 6-inch opening of the funnel. The frame was covered above with cold frame sashes to keep out the rain.

The collecting consisted in placing the sod on the wire mesh platform and recovering the larvae as they fell through the mesh and were concentrated into small pans of water by means of the funnels as the drying of the sod forced all animal life downward. By using eight 250 watt infrared heat lamps under the glass sashes and by covering the sashes with a tarpaulin at night, it was possible to maintain an air temperature of 90° to 100° F. over the sod even during the coolest summer nights. Such temperatures could be maintained on a sunny day without the use of lamps or tarpaulin. Practically all larvae fell to the pans below within 3 days and the entire layer of sod 3 inches thick could be completely air dried in 5 to 7 days.

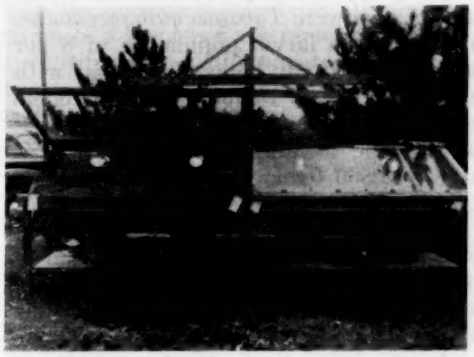

FIG. 3.—Apparatus used for drying sod.

During the 1948 season 72 square yards of sod were dried on this apparatus and 898 larvae including both genera were collected by this means.

As many as 120 larvae per square yard have been taken from the edge of a small stream which appeared particularly suitable as a larval habitat. Other square yard samples along the edge of this stream yielded 99, 58, and 14 larvae, respectively. Habitats having such high populations have been found along very gradually sloping banks of small pasture streams which were not over 2 or 3 feet wide and only several inches deep. An area of sod 2 yards square and 3 inches thick taken from under a canopy of trees in perpetually saturated soil, but without standing water, yielded 187 individual larvae containing *Chrysops* as well as *Tabanus*.

Of greater interest in this type of larval study are the observations made on the breeding habitats of *Tabanus quinquevittatus*. A systematic survey of sod collections in one pasture has shown a distinct correlation between soil moisture content and incidence of larvae of this species.

Moist but not wet soil forms environment where larvae of this important species were found. No larva was found in Zone 1 which was so wet that a depression soon filled up with water. In Zone 2, the potential larval area, where larvae were found in the upper 3 or 4 inches of root-bound soil, none were found at 4 to 8 inch levels which was also void of other forms of life on which the horsefly larvae are known to feed.

The greatest number of larvae taken per square yard in the potential larval area was 18. The majority of larvae found in this zone were *Tabanus quinquevittatus*. With a mean larval population of 8 per square yard it can be expected that with a 1 to 1 sex ratio 19,360 potential feeders could emerge per acre. Since this potential larval zone includes approximately 2.25 acres, 43,560 females could emerge from this area alone.

As yet no larvae of *Tabanus lasiopthalmus* or *T. sulcifrons* have been found in nature in New York, but larval collections along the edge of Zone 1 in completely saturated soil have yielded larvae which, as far as external appearance and coloration are concerned, are identical with larvae of the two species reared in the laboratory from known egg-masses. No definite statement, however, can be made until their emergence as adults.

Assuming that the identification of these larvae is correct, immature stages of *Tabanus lasiopthalmus* and *T. sulcifrons* apparently are restricted to soil having a narrower range of moisture than that tolerated by *T. quinquevittatus*. This may explain the consistently larger populations of the latter species.

SUMMARY.—The three species of horse flies of major importance on dairy animals in the Central New York area were *Tabanus lasiopthalmus*, *T. quinquevittatus*, and *T. sulcifrons* in the order of their seasonal occurrence. Infestations started in early June and lasted until early September. Above 72° F. fly activity seemed to be suppressed mostly by wind. Weighing fully engorged and unfed females of *T. quinquevittatus* indicated that a single fly could take an average of 71 milligrams or .074 cc. of blood; this species could consume 53 cc. of blood per animal per day during above normal fly populations. A single female of *T. sulcifrons* cold take 344 milligrams or .359 cc. of blood and under favorable conditions for fly populations this species could consume 115 cc. of blood per animal per day. These figures do not, by any means, indicate the maximum losses per animal since they do not take into account the loss of blood after the fly leaves the wound, nor the combined effects of *Chrysops* and populations of minor species of *Tabanus* feeding simultaneously with the major species. Larval collections made over a wide range of soil moisture conditions showed that tremendous populations are possible in a small area where conditions favor larval development. The abundance of *T. quinquevittatus* is probably explained by the adaptation of its larvae to a wide range of soil moisture, and consequently, its use of a more extensive breeding area.

Table 2.—Relationship of soil moisture and larval population in pasture sod as determined by recovery of larvae from drying sod.

No. Sq. Yd. Samples of Sod Dried	Range in Moisture Content of Soil	Average Larvae per Sample
8	22–29	0
5	30–49	1+
8	50–99	8
3	100+	10

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The Most Effective Termite Repellents

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The effectiveness of any chemical in preventing attack by the West Indian dry-wood termite, *Cryptotermes brevis* (Walker), depends not only upon the minuteness of the amount used but also on the permanence with which it continues to prevent attack over a series of years up to the anticipated service life of the wood treated. Tests initiated nearly 5 years ago indicate that samples of most susceptible wood submerged 10 minutes in 2 per cent solution of DDT or pentachlorphenol will not be attacked within the period of anticipated service and presumably these susceptible woods, externally at least, are permanently protected against termite attack. No other chemical has been under test for quite such a long period, but several have been effective for almost as long a period at somewhat or considerably greater dilutions. On the score of minuteness of amount used, as well as permanence, they would appear to be more effective than DDT and pentachlorphenol.

Of the numerous chemicals which are initially toxic or repellent, or both, but cease to be either toxic or repellent after a shorter or longer time, no mention has been made in the accompanying table. Many of these have been discussed, as well as the testing technique, in a recent publication[1]. It should be emphasized that the lack of permanence of these chemicals by no means limits their value for other insecticidal purposes. Indeed, for the protection of greenwood or bamboo against insects which attack it only while it is being seasoned, such chemicals may be quite as desirable as those which are more permanent in their effect. Pure gamma isomer of benzene hexachloride at 0.01 per cent will prevent termites from eating treated wood for over 4 months, and 1 per cent for nearly a year. Thus it would be effective against powder post beetles during the period when they are most likely to cause injury. The plant extractive ryanodine at 0.02 per cent is toxic immediately, and repellent for at least 4 months after application to the wood but has been available for test for such a short time that no statement can be made as to its permanence. Chlordan has quite a different reaction, for although toxic to termites for a few days, within 2 months after treatment with 0.5 per cent the wood sample is eaten with impunity. That impregnated with 1 per cent of chlordan, however, was not eaten until over a year after treatment, indicating that chlordan in this respect was comparable to gamma benzene hexachloride.

In the accompanying table, the implication of a record of a sample of termite-susceptible wood still uneaten a certain length of time after having been impregnated with a chemical at a certain concentration is that lesser concentrations of that chemical failed to protect for a shorter period similar wood samples of the series. Thus the wood sample impregnated with 1 per cent DDT was eaten in 37 days, and that with 1 per cent pentachlorphenol in 337 days, but one should not conclude that this gives any indication as to when the samples treated with 2 per cent of these chemicals may be attacked. Indeed, that they have not been eaten in nearly 5 years may indicate that they have been rendered permanently resistant, and that they never will be eaten. For actual use however, at least twice as great a concentration should be used to provide an ample margin of safety. Moreover, it should be stressed that even a greater concentration will not permit any carelessness or lack of thoroughness in application to every exposed surface of the wood being treated.

Most surprising is the record of the pentachlorphenate of sodium, better than of lead or zinc, or than any of the intrinsically toxic metals except copper. Furthermore, it is cheap and commercially available in large quantities. It is water-soluble, which places it in the class with copper sulfate and zinc chloride as being also subject to leaching, although this is a characteristic of little importance so far as the environment inhabited by dry-wood termites is concerned. Copper pentachlorphenate, on the contrary, is insoluble in many common solvents, but for application to wood is amply so in alcohol.

[1] Agricultural Experiment Station, Univ. of Puerto Rico, Bull. 73: 18, 1947.

Table 1.—The length of time that samples of wood most susceptible to termite attack have been protected from *Cryptotermes brevis* (Walker) by submergence for 10 minutes in solutions of the chemicals listed.

Compound	Per Cent Strength	Results Observed
Copper Pentachlorphenate	0.1	uneaten 4 years
Sodium Pentachlorphenate	0.2	uneaten 3 years 10 months
Ferric Iron Dimethyldithiocarbamate	0.5	uneaten 4 years 8 months
Copper Dimethyldithiocarbamate		over two years
Zinc Dimethyldithiocarbamate		over two years
alpha-Naphthoflavone		3 years 3 months
Xanthone		3 years 3 months
Pyridyl Mercuric Chloride		3 years
Pyridyl Mercuric Stearate		3 years
Zinc Lake (Acetic Acid) Chrysazin		2 years
Hexachlorphenol	1.0	uneaten 4 years
Pentabromophenol		4 years
Diphenyl Mercury		3 years 7 months
Phenyl Mercuric Chloride		3 years 7 months
beta-Methyl Anthraquinone (Tectoquinone)		3 years 3 months
Zinc Lake (Acetic Acid) Quinizarin		2 years
Zinc Lake (Acetic Acid) beta-chlorAnthraquinone		2 years
Genicide Acids		1 year 7 months
4,6-Dinitro-O-Sec-Butyl Phenol		1 year 2 months
Piperonyl Cyclohexenone		1 year
DDT	2.0	uneaten 4 years 9 months
Pentachlorphenol		4 years 9 months
Triphenyl Stibine		3 years 7 months
Triphenyl Phosphite		3 years 3 months
Diphenyl Selenium		1 year 9 months
2,4-Dichlorphenyl Potassium Monochlor-Acetaldehyde Disulfonate		1 year 8 months
1,1-Diphenyl (4-hydroxy-3,5-dichlor) 2,2,2-Trichlorethane		over 1 year 5 months
Chlorinated Anacardic Acid	5.0	4 years
Tetrachlorphenol		4 years
Chlorinated Crude Cardol		3 years 6 months

The alcoholic solutions may be very considerably diluted with water before precipitation occurs. It is a dark purplish powder, but dilute solutions are practically colorless, and treated wood is practically unchanged in appearance, and has no noticeable odor.

Ferric iron dimethyldithiocarbamate,[1] is a fine black powder, soluble in acetone, which stains light-colored woods dark grey. Wood samples impregnated with fermate, or with the copper or zinc salts of dimethyldithiocarbamate, are toxic to termites for a long period. The zinc compound is a white powder, the copper a dirty brown powder, but wood samples impregnated with them are not noticeably stained. Theoretically, they should be more toxic than the ferric iron salt. Samples were prepared submerged in solutions in acetone at no greater strength than 0.2 per cent, and when these were attacked nearly 2 years later it seemed too late to prepare fresh samples at the greater concentrations which presumably would never be eaten.

When tests were being made of the various constituents of termite-resistant woods, alpha-naphthoflavone[2] happened to be included. It is a very expensive chemical, looking like coarse granulated sugar, soluble in acetone up to nearly 2 per cent and to some extent dilutable with water without precipitation, not staining or otherwise apparently altering the appearance or odor of the treated wood. It is hardly to be expected that it will be used commercially. Tectoquinone (beta-

[1] *Fermate.*
[2] Eastman.

methyl anthraquinone) is an extractive of East Indian teakwood (*Tectona grandis*), and may be the factor responsible for its well-known resistance to decay and insect attack. Crude cardol and anacardic acid are extractives of the husk of cashew nuts (*Anacardium occidentale*), being very toxic to man as well as to insects. They and chlorinated compounds are very dark brown in color, deeply staining impregnated wood, and imparting to it a permanent and quite characteristic odor. Eventually, however, the termites burrow through this stained outer layer at 2 per cent of impregnation, but to date the samples treated with 5 per cent are uneaten.

Xanthone, soluble in acetone, is twice as effective as tectoquinone and costs ten times as much. It is commercially available as an insecticide.[1] and may find extensive application for wood impregnation. A by-product of its manufacture[2] is less effective, and has been available for tests for a comparatively short period. Tetrachlorxanthone, initially more repellent than xanthone, in less than 2 years fails to protect wood samples at one per cent and at 2 per cent, and dichlorxxanthone and dibromoxanthone are of but the most temporary value. The methyl and benzol compounds of xanthone have been under test for too short a time to prove their preliminary promise.

The pyridyl mercuric compounds have been made commercially available by Mallinckrodt. The chloride may be dissolved in pyridine, and diluted with water without danger of precipitation. After the pyridine has evaporated the treated sample is odorless and unchanged in color.

The acetic acid lakes combining zinc with quinone dyes were prepared by Miss Yolanda Pirazzi of the Rio Piedras Station. Darkly opaque pink or reddish-brown in color, they superficially stained the wood samples. This may be an advantage. It definitely proves to casual inspection that the wood has been treated, and promptly indicates any part which has not been reached by the colored solution. The 4, 6-dinitro-o-sec-butyl phenol is a powerful yellow dye, which may not eventually prove to be the most permanently effective of the dinitro compounds for wood impregnation. Many are being tested, but this was the one found[3] to be the most toxic to plants, and was earliest made available for preliminary experimentation.

The effect of the extent of chlorination of phenol is most beautifully illustrated by the decreasing amounts of tetrachlorphenol, pentachlorphenol and hexachlorphenol needed to prevent termite attack. The greater effectiveness of bromination rather than of chlorination is also quite obvious. The selection of the other phenol compounds is largely based on availability rather than on theoretical effectiveness. If diphenyls and triphenyls of ferric iron, lead, zinc and copper are ever synthesized, they may prove to be more effective in protecting wood against dry-wood termite attack than any of the chemicals which have been available for experimentation.

[1] *Genicide* of General Chemical Co.
[2] Called *Genicide acids*.
[3] By Dr. A. S. Crafts of the Davis California Station, temporarily in Puerto Rico in 1947–48.

DR. WORTHLEY NAMED EXECUTIVE DIRECTOR OF COMMITTEE ON CHEMICAL WARFARE

Dr. Harlan N. Worthley, director of the agricultural and textile chemicals research department of Merck & Co., Inc., Rahway, N. J., since March, 1946, was appointed executive director of the Committee on Chemical Warfare of the Research and Development Board, National Military Establishment. Dr. W. Albert Noyes, Jr., chairman of the committee, announced that Dr. Worthley will assume his duties January 3, 1949.

Dr. Worthley was graduated from Massachusetts Agricultural College with a Bachelor of Science degree in 1920. He received his Master of Science degree from the same school in 1923, and his Ph.D degree in entomology from Ohio State University in 1939. While at Pennsylvania State College from 1925 to 1945 he was an assistant professor, associate professor, and then professor of economic entomology. On leave of absence from August, 1942, he served as a major, lieutenant colonel and colonel in the Chemical Corps until January, 1946. He is a member of the Officers' Reserve Corps, and until recently has been commanding officer of the 1998th O. R. Research and Development Group, First Army, located at Newark, N. J.

Livestock Parasite Control Investigations and Demonstrations in Brazil

E. W. Laake[1]

External parasites of livestock are directly responsible for serious injury and tremendous losses to the Brazilian cattle industry. National and State officials have long recognized the great need of efficient materials and improved methods for insect control in order to increase a badly needed supply of beef, milk, leather, and other beef and dairy products, all of which are so vital to the health and living standards of the nation.

At the request of Dr. Daniel de Carvalho, Minister of Agriculture of the United States of Brazil, and Dr. Americo Giannetti, Secretary of Agriculture of the State of Minas Gerais, the American International Association for Economic and Social Development arranged for a series of investigations and demonstrations in livestock-parasite control. The American International Association for Economic and Social Development is a non-profit membership corporation of which Mr. Nelson A. Rockefeller is president. Its goal is to contribute to the development of higher standards of living and opportunities for self-development among people of various countries. It was obvious to all concerned that the possibilities for increased livestock products in Brazil were tremendous if an extensive means of livestock-pest control were developed and publicized. In response, the American International Association instituted the livestock control investigations as an A. I. A. Project in Brazil, and the author, who was greatly interested in trying to spread into Latin America the findings of his Bureau in this important field, was kindly granted permission by the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture to go on leave for two and one-half months for the purpose of this project.

Except for very brief stops on the way to and from Brazil at the Inter-American Institute of Agriculture at Turrialba, Costa Rica, the National Livestock Exposition at David, Panama, and the farms of the International Basic Economy Corporation at Caracas, Chirgua, and Agua Blanca, Venezuela, to observe the external parasite problems of local livestock, all of this period was devoted to testing some of the more promising new chlorinated hydrocarbon insecticides and rotenone for the control of ticks, lice, flies, and grubs in Brazil. The tests and demonstrations were made on dairy cattle on the fazenda of the Inspetoria Regional de Pinheiral, the Fazenda Experimental Santa Monica, both federal experimental stations, and on the private fazenda of Sr. Edwardo Duvivier, all located in the State of Rio, and on the private fazendas of Sr. Silvo Bastos and Sr. Severino Junqueira in the State of Minas Gerais.

The animals and facilities that had been selected by Brazilian and A. I. A. personnel were suitable for our demonstrations and tests and the personnel on the test farms rendered marvelous cooperation.

External Livestock Parasites and Their Abundance in South America.—The external parasites of livestock in Brazil and in all other countries visited consisted of ticks, mostly the fever tick *Boophilus microplus;* the grub *Dermatobia hominis,* known in Brazil as "Berne" and in Central America as "Gusano," or "Gusano de Monte," or "Torsalo"; the tail louse of cattle, *Haematopinus tuberculatus;* the house, stable, horn, screw, worm, and horse flies; and mosquitoes. During the period of our tests at least 90 per cent of all external parasites present on cattle in Brazil were ticks and *Dermatobia* grubs. This was the beginning of the dry, or winter, season (April and May) of the year, which is claimed to be particularly favorable for ticks, while the grubs reach their greatest abundance during the wet, or summer, season of the year. These two parasites were each extremely abundant and undoubtedly are more destructive to cattle than any parasite of cattle, including the cattle grubs, in the United States.

The extremely heavy tick populations on all the test farms in Brazil were all the more interesting because of the rather

[1] Consultant, American International Association for Economic and Social Development, on leave from Bureau of Entomology & Plant Quarantine, United States Department of Agriculture.

systematic program of dipping in arsenical cattle dips containing arsenious oxide as the active tick-killiing agent to which the cattle had been subjected for years. It was evident that this dip was not killing all the ticks attached to the animals at the time of treatment or preventing their reinfestation immediately after the treatment. It apparently had no effect either on the encysted *Dermatobia* larvae or on the carriers of the eggs of the *Dermatobia* fly. This grub is undoubtedly the most serious pest affecting cattle in any of the Americas, and everything posssible should be done to prevent its introduction and establishment in the United States.

House flies were abundant in the dairy barns of two of the test farms, but not so on the others. Stable flies were present everywhere, but only in moderate numbers. There were few or no horse flies and rather few cases of screw-worms in Brazil during the period of our tests, but these pests are known to be more serious during the summer season of the year. In Venezuela screw-worms constituted one of the more serious pests late in May, but here too, and also in Panama and Costa Rica, the fever tick and the *Dermatobia* grub constituted by far the most serious and damaging external parasites of cattle. Tail lice of cattle were present on two of the test farms in Brazil, in spite of dipping in the arsenical bath to which the infested animals had been subjected for several years. Mosquitoes were noted in all areas visited, but did not appear in annoying numbers anywhere, especially in Venezuela where DDT is widely used for their control. Our observations in all areas visited showed that the fever tick and *Dermatobia* grubs were the two external parasites present in greatest abundance and devastating to the cattle industry in Central and South America to an extent far beyond the damage inflicted today by any external parasite of cattle in the United States. Screw-worms are also a problem in Central and South America almost the year around, but particularly so during certain seasons of the year. Although the various species of blood-sucking flies and mosquitoes were not present in sufficient numbers to inflict any considerable amount of damage as a result of their own depredations, they must, however, be recognized as being of great importance because they are the carriers of the eggs of the *Dermatobia* fly.

INSECTICIDES TESTED IN BRAZIL.—In view of the importance of developing a new insecticide superior to the arsenical solution for the control of the fever tick and possibly also for the control of *Dermatobia* grubs during the extremely limited time allowed for this study, it was necessary to confine our investigations to evaluating the merits of three of the most promising new chlorinated compounds, namely, toxaphene, DDT, and benzene hexachloride, which under extensive field testing had consistently given good results for the control of ticks, lice, and flies on animals in the United States, and rotenone, which is the only material that has been effective for the control of the two North American species of cattle grubs.

The new insecticides for the control of livestock parasites were introduced in Brazil on April 5, 1948, when, for the first time, Brazilian cattle heavily infested with the fever tick were sprayed with an emulsion of toxaphene applied with a power sprayer. An emulsifiable concentrate containing 50 per cent toxaphene was used for making the spray. The first animals sprayed were red Holstein and brown Swiss cows in the milk herd on the fazenda of the Inspetoria Regional de Pinheiral. Approximately 80 other cattle, all pure-bred Brown Swiss cows and heifers, on this farm were sprayed on the same day with a mixture of DDT and benzene hexachloride. A 35 per cent DDT emulsifiable concentrate and a 50 per cent benzene hexachloride wettable powder containing 6 to 6.5 per cent gamma isomer were used for making the spray mixture.

The power sprayer used in Brazil was a John Bean, medium size, simple, but very rugged machine, powered by a Wisconsin 4-horse power gasoline engine and capable of delivering seven gallons of spray per minute at a nozzle pressure of 400 pounds per square inch. The sprayer was equipped with nozzles and other attachments, including the underline sprayer, developed by the manufacturer for livestock spraying. The application of the spray to the animals was made while they were momentarily confined in an ordinary cattle chute constructed of iron pipe. The animals were thoroughly covered with the spray applied with two two-nozzle booms.

At this and at all of the other test farms

where the new chlorinated hydrocarbon compounds were used for the control of ticks, animals quite comparable to those treated with the new insecticides were dipped in the standard arsenical cattle dip to serve as controls for the experimental groups. Counts or estimates of the number of ticks on the test area of the treated and control animals were made at weekly intervals until the test materials failed to protect the animals from reinfestation.

The results obtained in this and in the other tests described below were combined for each concentration or combination of materials and are given in table 1. Abbot's formula was used for calculating the per cent control of ticks.

It should be noted that the check cattle were not untreated animals, but animals that were dipped in the arsenical bath at 15-day intervals throughout the period of this test. In spite of this, these cattle were always well- to heavily-infested with all stages of the fever tick, indicating that the systematic dipping in the arsenical bath did not free the animals from all the ticks attached at the time of treatment or prevent their reinfestation soon after treatment. Moreover, we observed that some of the animals had been rather severely blistered and that all of them showed light injury as a result of repeated dippings in the arsenical bath. This condition was observed at all of the test farms and was also reported from others that were using the arsenical bath in an attempt to control the fever tick.

The test animals on the Santa Monica, Duvivier, Bastos, and Junqueira fazendas were treated April 6 to 9, inclusive. Systematic dipping in the arsenical dip, at 15-day intervals, for the control of ticks had been practiced for years, but with very poor results and considerable blistering of the animals. It was pointed out by the personnel on the Santa Monica and Duvivier fazendas that it was necessary to remove the engorging adult ticks daily by brushing them off the animals with curry combs because the dip did not destroy all of them and that dipping the cattle more often than now practiced or in a stronger solution of arsenic would be very dangerous to the health of the animals. Here, as elsewhere in Brazil, it was quite evident that the systematic dipping of cattle in the arsenical solution over a period of years had undoubtedly resulted in developing a strain of fever tick distinctly resistant to the standard arsenical dip. In order to keep one of the premium Holstein bulls on the Duvivier fazenda free from ticks, which was not possible with the use of the arsenical solution without endangering his health, a native boy was employed to remove the ticks from this fine animal by picking them off by hand daily. This task required several hours of the boy's time daily until the animal was sprayed with 0.5 per cent toxaphene, which kept him free from ticks for 4 weeks, and he was only very lightly infested at the end of 5 weeks, when he had gained over 100 pounds.

House flies were very abundant in the dairy barns on the Duvivier fazenda, especially in the Holstein barn. In order to control this pest the Jersey dairy barn and calf stalls were sprayed inside with 0.5 per cent toxaphene emulsion. The Holstein barn and calf stalls, located about 2 miles from the Jersey barn, were sprayed with 5.0 per cent DDT emulsion.

On both the Bastos and Junqueira fazendas cows heavily infested with tail lice were present in the test herds. Observations were made at approximately weekly intervals to determine the effectiveness of the test materials for the control of this louse, which is apparently more resistant to insecticides than either our short- or long-nosed cattle louse in the United States.

In addition to the investigations in Brazil with the new chlorinated hydrocarbon insecticides for the control of ticks, lice, and flies, the author also investigated the possibility of destroying the encysted larvae of the "Berne" fly *Dermatobia hominis*, by high pressure spraying with rotenone. For this purpose, three lots of Zebu steers on the Duvivier farm and one lot of Holstein cows on the Junqueira farm were treated with amounts varying from 4 to 16 pounds of finely ground cube powder containing 4.7 per cent rotenone in 100 gallons of water. The cube suspensions were applied at very close range as a driving spray with 400-pounds nozzle pressure to the "Berne"-infested areas on the cattle.

In other tests on the Bastos fazenda a cube suspension containing 20 pounds of cube powder, 4.7 per cent rotenone, per 100 gallons of water was thoroughly ap-

plied to encysted "Berne" larvae as a wash, and, to insure contact with the deeply encysted larvae, the suspension was also injected directly into a number of active "Berne" cysts. Since many of the dairy animals sprayed with toxaphene and with the mixtures of DDT and benzene hexachloride were infested with "Berne" larvae in all stages of development, we also had an excellent opportunity to study the effects of these new chemicals on the encysted larvae.

SPRAYING AND DIPPING DEMONSTRATIONS IN BRAZIL.—A thousand cattle, including young calves, on the Bastos fazenda were dipped in 0.53 per cent toxaphene emulsion. A 50 per cent toxaphene emulsifiable concentrate was used for making the dip. The dipped animals were freed from very heavy infestations of all stages of the fever tick within 48 to 72 hours after treatment. Our observations for 2 weeks and the owner's reports thereafter indicated that this dip protected the cattle from reinfestation by the fever tick for approximately 4 weeks. In subsequent reports the owner stated that the dipping of his cattle in this vat at monthly intervals had given excellent results for controlling the fever tick.

On the Duvivier fazenda a considerable number of Holstein cattle of various ages were dipped in 0.5 per cent DDT emulsion made from a 30 per cent DDT emusifiable concentrate. This dip failed to kill all of the partly to fully engorged fever ticks, and the animals became reinfested with larval ticks approximately 2 weeks after dipping.

On May 11 a spray demonstration was given on the fazenda of the Federal Inspetoria Regional de Pinheiral. The demonstration, in which all the cattle on this experimental station were sprayed with 0.5 per cent toxaphene emulsion applied with the power sprayer, including the underline spraying device, was given for His Honor, Dr. Daniel de Carvalho, Minister of Agriculture of the United States of Brazil, his staff, representatives of the Brazilian Senate and Congress, and a number of distinguished farmers and guests who came to the demonstration on a special train provided by the Ministry. They were all intensely interested to see a highly efficient and modern, yet simple, procedure for rapidly treating animals for the control of external parasites.

DISCUSSION OF RESULTS.—The excellent results obtained with some of the chlorinated hydrocarbon insecticides, particularly toxaphene, as compared to the miserable results obtained from the arsenical solution for the control of the fever tick in Brazil are shown in table 1. The data in this table show that:

1. Toxaphene applied as a spray destroyed all stages of the fever tick, *Boophilus annulatus* var. *microplus*, attached to cattle at the time of treatment and prevented reinfestation for 3 to practically 4 weeks, depending somewhat on the breed of cattle involved. The toxaphene emulsion used in our spray tests in concentrations of 0.25, 0.50, and 0.75 per cent and in dip tests at 0.53 per cent active principle was applied to four purebred breeds and several grades or mixtures of dairy breeds, including young and very young purebred and grade calves, without any visible injury to the animals or to the personnel handling or applying the emulsion.

2. The mixtures of DDT and benzene hexachloride quickly destroyed all stages of the fever tick at the time of treatment and prevented reinfestation of the treated animals for 13 days after treatment. Protection from reinfestation after one treatment with the mixtures of DDT and benzene hexachloride was definitely less effective than the protection obtained from toxaphene. No injury resulted either to the treated animals or to the personnel applying the benzene hexachloride-DDT mixtures used in our tests. DDT applied as a dip at a concentration of 0.5 per cent did not kill all of the partly engorged fever ticks and did not protect animals from reinfestation longer than 2 weeks.

3. The arsenical solution, used almost exclusively in Brazil in an attempt to control the fever tick, and which was used as a check in our tests, failed to kill all the ticks attached to the animals at the time of treatment and did not prevent their reinfestation immediately after treatment.

Moreover, it was observed at all of the test fazendas that some of the cattle had been rather severely blistered and that practically all of them showed some skin injury as a result of repeated dippings in the arsenical bath. It was pointed out by the personnel on several of the test fazendas that it was necessary to remove the engorging adult ticks daily by brush-

Table 1.—Results of tests with toxaphene and combinations of benzene hexachloride and DDT for the control of the cattle fever tick, *Boophilus annulatus* var. *microplus*, in Brazil, April and May, 1948.

Material and Concentration	Number Cattle Treated	Average No. Ticks Before Treatment[1]	Per Cent Reduction in Ticks After Weeks Indicated—			
			1	2	3	4
Toxaphene 0.25% emulsion	20	450	100	100	97.3	91.0
Toxaphene 0.5% emulsion	172	400	100	100	100	88.2
Toxaphene 0.75% emulsion	41	475	100	100	99.7	85.2
Benzene hexachloride 0.25% WP plus 0.25% DDT emulsion	104	380	100	94.2	77.6[2]	42.3[3]
Benzene hexachloride 0.25% WP plus 0.5% DDT emulsion	119	450	100	97.6	82.5[2]	49.3[3]

[1] Estimated number of larvae, nymphs and adults on 1 square foot of skin covering the escutcheon and upper portion of udder. Number given is the average of 10 cows.
[2] Larvae and young nymphs present.
[3] Larvae, nymphs, and few young adults present.

ing them off the cows because the dip did not destroy all of them, and dipping the cows more often than is now practiced or in a stronger solution of arsenic would be very dangerous to the health of the cattle.

4. Data obtained but not included in table 1 show that:

(a) Barns and stalls sprayed with 0.5 per cent toxaphene emulsion or with 5.0 per cent DDT emulsion quickly eliminated heavy populations of house flies and kept the buildings practically free from flies for 6 weeks, when the observations were discontinued.

(b) Toxaphene and mixtures of DDT and benzene hexachloride in the formulations and concentrations given in table 1 eradicated the tail louse, *Haematopinus tuberculatus*, with a single treatment, whereas rotenone-bearing powder in suspensions killed only the crawling stages of the louse and failed to eradicate this pest with one treatment. The arsenical solution was ineffective in controlling this louse even with repeated treatments.

(c) Suspensions containing 4, 8, 12, and 16 pounds cube powder per 100 gallons of water and applied at close range as a driving spray with 400-pounds nozzle pressure were ineffective for controlling the deeply encysted second- and third-stage larvae on the "Berne" fly, *Dermatobia hominis*. Cube powder applied at the rate of 20 pounds per 100 gallons as a wash thoroughly rubbed in with very stiff brushes, also failed to kill the "Berne" larvae. Injections of the heavy suspension, as used for the wash, directly into the "Berne" cysts also failed to kill all the large larvae but apparently caused some of the larvae to disappear from the cysts within a week after treatment.

(d) Toxaphene and mixtures of benzene hexachloride and DDT as listed in table 1 had no effect on the encysted "Berne" larvae.

(e) Observations in Costa Rica, Panama, Venezuela, and Brazil revealed *Dermatobia* infestations in almost every herd of cattle inspected. Relatively few animals were entirely free from this pest, which undoubtedly is the most serious and damaging parasite of cattle in Central and South America.

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Two Butoxypolypropylene Glycol Compounds as Fly Repellents for Livestock[1]

PHILIP GRANETT, HARRY L. HAYNES,[2] DONALD P. CONNOLA, THOMAS G. BOWERY and GEORGE W. BARBER, *Rutgers University,*[3] *New Brunswick, N. J.*

During the past 4 years the fly repellency properties of some polyalkylene glycol derivates have been under investigation. Of these, two compounds are of particular interest. Both of these are butoxypolypropylene glycol compounds, one with an approximate molecular weight of 400, and the other with a molecular weight of approximately 800.[4] The 400 molecular weight fraction is characterized by having an average molecular weight of 400, a vapor pressure at 30° C. below 1×10^{-2} mm. Hg, a flash point of approximately 375° F., a specific gravity at 20° C./20° C. of 0.973, a water solubility of 0.2 parts by weight in 100 parts of water, and an average weight at 20° C. of 8.3 pounds per gallon. The 800 molecular weight fraction is characterized by having an average molecular weight of approximately 800, a vapor pressure at 30° C. of 1×10^{-3}, a flash point of approximately 420° F., a specific gravity at 20° C./20° C. of 0.990, a water solubility of 0.1 parts by weight in 100 parts of water, and an average weight at 20° C. of 8.25 pounds per gallon.

LABORATORY TESTS.—The initial tests with these compounds were in the laboratory at Boyce Thompson Institute, using a modification of the Kilgore bait method (1939). Three cc. of a 50 per cent solution of butoxypolypropylene glycol 800 in ethanol were sprayed on replicated 1 by 3 inch strips of white blotting paper. The paper had been previously punched with five holes, evenly spaced. The blotting paper was laid on a wax paper surface and a bait[5] put in each of the holes before each test. Each treated strip was then exposed to house flies, *Musca domestica* L., under a wire mesh hemispherical cage along with an unsprayed baited strip. It was observed that feeding was reduced 90 to 100 per cent for 4 days, and 80 to 90 per cent for 13 days. By comparison, n-butyl mesityl oxide oxalate,[6] reduced feeding 68 per cent at the end of 4 days.

Butoxypolypropylene glycol 400 in the same type of test conducted over a period of 6 days reduced feeding by 91 per cent. Butoxypolypropylene glycol 800 reduced feeding by 96 per cent, and n-butyl mesityl oxide oxalate by 86 per cent.

FIELD TESTS IN NEW JERSEY.—In one of the first attempts at verifying the laboratory findings that butoxypolypropylene glycol 800 was an effective fly repellent, a field test was conducted using the "half cow" method. One half of the cow was treated with 50 cc. of spray material, the other half being covered with a tarpaulin at the time of spraying. The cows were sprayed in the barn and soon thereafter turned into the pasture. Counts of flies, mainly stable flies, *Stomoxys calcitrans* (L.), plus some horn flies, *Siphona irritans* L., were made at 2-hour intervals on both sprayed and unsprayed sides. The cows were a mixed group of Holstein, Ayreshire, Jersey and Brown Swiss. The results, shown in table 1, indicate that butoxypolypropylene glycol 800 at concentrations of 5 and 20 per cent provided approximately 80 per cent repellency of flies as compared to the unsprayed check. This was decidedly better than either n-butyl mesityl oxide oxalate or isobornyl thiocyanoacetate.[7]

A series of "half cow" tests involving 4 to 13 cows per material were made the following year, 1946. In these tests, summarized in table 2, it appears that butoxypropylene glycol 800 afforded approximately 60 per cent protection when used at 10 per cent in oil and was 10 per cent less effective when applied in aqueous emulsion. On the other hand, butoxypolypropylene glycol 400 was more effective in water, approximately 70 per cent, and gave 50 per cent repellency when used in oil.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.
[2] Senior Fellow in Entomology, Boyce Thompson Institute for Plant Research, Inc., Yonkers, New York.
[3] Investigations conducted under research fellowships sponsored by Carbide and Carbon Chemicals Corp. at Rutgers University and at Boyce Thompson Institute.
[4] Sold under the trade name Crag Fly Repellent by the Carbide and Carbon Chemicals Corp., New York City.
[5] *Diamalt*—Standard Brands Corp., New York City, or molasses.
[6] *Indalone*—U. S. Industrial Chemicals Corp., Baltimore, Md.
[7] *Thanite*—Hercules Powder Co., Wilmington, Del.

Table 1.—Repellency of chemicals in "half cow" test against flies, mainly *Stomoxys calcitrans* (L.) and *Siphona irritans* (L.). Sept. 24, 26, 1945, New Brunswick, N. J.

Material and Concentration	2 Hours No. Flies			4 Hours No. Flies			6 Hours No. Flies			Total Flies		
	U.	S.[1]	Per Cent Repellency[2]	U.	S.	Per Cent Repellency	U.	S.	Per Cent Repellency	U.	S.	Per Cent Repellency
Butoxypolypropylene glycol 800												
20%	11	3	73	10	3	70	14	2	86	35	8	77
	19	2	90	4	0	100	6	2	67	29	4	86
5%	11	2	82	14	1	93	8	1	87	33	4	88
n-Butyl mesityl oxide oxalate												
20%	24	3	88	53	20	62	11	14	0	88	37	58
iso Bornyl thiocyanoacetate												
20%	5	5	0	25	10	60	5	2	60	35	17	51
	15	5	66	21	6	71	14	3	78	50	14	72
5%	28	14	50	36	12	66	23	6	74	77	32	60
Base Oil	14	13	7	18	15	17	27	20	26	59	48	18
Untreated	30			35			30			95		
	28			24			17			69		
	27			31			28			86		
	23			29			20			72		

[1] U = Unsprayed side. S = Sprayed side.

[2] $\%\ \text{Repellency} = \frac{\text{Unsprayed} - \text{Sprayed}}{\text{Unsprayed}} \times 100$

Table 2.—Repellency of chemicals in "half cow" test against flies, mainly *Stomoxys calcitrans* (L.) and *Siphona irritans* (L.). September 1946, New Brunswick, N. J.

Treatment 10 Per Cent Concentrations Used	No. of Cows	Average Per Cent Repellency for Counts Made on Legs and Body At:						Total Flies		
		2 Hrs.	3 Hrs.	4 Hrs.	5 Hrs.	6 Hrs.	7 Hrs.	U.	S.	Per Cent Repellency
Butoxypolypropylene glycol 800 in oil	13	83	54	61	66	40	60	425	177	58
Butoxypolypropylene glycol 800 in water	8	38	75	40	32	34	65	257	132	48
Butoxypolypropylene glycol 400 in oil	8	67	60	40	24	19	89	282	147	49
Butoxypolypropylene glycol 400 in water	4	42	94	68	72	78	81	135	36	73
Iso bornyl thiocyanoacetate in oil	11	61	76	44	62	18	90	232	109	57
Base oil	11	10	26	13	30	23	12	490	396	19
		Total Number of Flies per Side								
Untreated	8	81	101	106	127	126	88	629		

During the past season (1948), the whole cow method was used; that is the entire cow was treated except the head with 150 cc. of spray. In order to avoid the discrepancies introduced by differences in cow's susceptibility to attack, an experiment was set up whereby each cow in the trial received each treatment. In the present instance, five materials were used, plus an untreated check. The rotation scheme involving the six cows is shown in table 3. One hundred fifty cc. of each spray was applied every other day, although counts were recorded five times every day in order to determine if there was any repellent effect the day following treatment. The treatments consisted of butoxypolypropylene glycol *800*, butoxypolypropylene glycol *400*, and n-butyl mesityl oxide oxalate at the rate of 10 per cent in oil[1] and 10 per cent butoxypolypropylene glycol 400 emulsified with 0.5 per cent polyethylene glycol dioleate 600 emulsifier and 10 per cent butoxypolypropylene glycol *400* emulsified with an alkylated aryl polyether alcohol.[2]

A summary of the counts made for the entire series of tests is recorded in table 4. In these trials, butoxypolypropylene glycol 400 in oil was found most effective on the day it was applied, giving 75 per cent protection. This chemical in water was about as effective as butoxypolypropylene glycol 800 in oil. The comparison material, n-butyl mesityl oxide oxalate in oil, provided less than 50 per cent control.

The counts made the day after spraying revealed that under these conditions only butoxypolypropylene glycol 800 in oil appeared to have any appreciable residual repellent action. About 50 per cent control was obtained from this material at that time as compared to none for n-butyl mesityl oxide oxalate, and 28 per cent for butoxypolypropylene glycol 400 in water, and 7 per cent for butoxypolypropylene glycol 400 in oil. The rotating checks on which repellency comparisons were based had about a third fewer flies than did cattle in the same field that received no sprays. Consequently, the degree of repellency would be greater if comparisons had been made with the unsprayed cows.

TEST ON HORSES.—A repellency test was made on horses being bitten by equal numbers of *Stomoxys calcitrans* and *Tabanus* spp. In order to determine susceptibility of the horses to fly attack, they were staked to a fence the day prior to spraying (July 23, 1948) and counts made of the number of flies on legs and body. The repellents to be tested were applied to the animals beginning at 9:00 A.M. on July 24. The animals were then tied to the identical positions in the picket line that they had occupied on the day before. Observations of fly populations on the animals were made hourly from 9:30 A.M. to 2:30 P.M. and ended at 3:30 P.M. because of rain. A comparison of the total fly populations found on each of the animals before and after spraying with repellents is given in table 5.

Table 3.—Rotation scheme in which each of six cows was sprayed every other day with a different material so that each cow received a treatment with each material to be tested.[1] Experiment begun August 25, 1948, New Brunswick, N. J.

NUMBER OF COW	BREED	DAY SPRAYED: 1st	3rd	5th	7th	9th	11th
H 46	Holstein	A	B	C	D	E	F
645	Brown Swiss	B	C	D	E	F	A
633	Brown Swiss	C	D	E	F	A	B
A 1	Ayreshire	D	E	F	A	B	C
A 2	Ayreshire	E	F	A	B	C	D
J 3	Jersey	F	A	B	C	D	E

[1] A = Butoxypolypropylene glycol *400*.
B = Butoxypolypropylene glycol *800*.
C = n-Butyl mesityl oxide oxalate.
D = Butoxypolypropylene glycol *400* plus emulsifier, polyethylene glycol dioleate *600*.
E = Butoxypolypropylene glycol *400* plus emulsifier, (*Triton X-100*).
F = Check.

[1] *Deobase*.
[2] Alkylated aryl polyether alcohol, Rohm and Haas Co.

Table 4.—Results of rotation experiment with sprayed cows. Cows examined at 2 hour intervals over a period of 8 hours.

MATERIAL	TOTAL NUMBER OF FLIES FOUND ON ALL TREATED COWS AND PER CENT CONTROL OVER UNTREATED STOCK: Day of Treatment No.	Day of Treatment Per Cent Control	Day After Treatment No.	Day After Treatment Per Cent Control
Butoxypolypropylene glycol 400	177	75.7	466	7.3
Butoxypolypropylene glycol 800	188	61.0	268	46.7
n-Butyl mesityl oxide oxalate	255	47.2	522	0
Butoxypolypropylene glycol 400 plus emulsifier[1]	170	64.8	365	27.4
Butoxypolypropelene glycol 400 plus emulsifier[2]	190	60.0	362	28.0
Untreated check	483		503	
Permanent check[3]	673		598	

[1] Emulsifier polyethylene glycol dioleate 600.
[2] Emulsifier *Triton X-100*.
[3] Average of four cows not in rotation plan but always in same pasture.

Table 5.—Apparent reduction of population of flies, *Stomoxys* and *Tabanus* spp., on horses, obtained by application of repellents. August 23, 24, 1948.

Material	Horse[1] No.	Number of Flies and Per Cent Control Over Previous Day Count: Total Number Before Spraying	Total Number After Spraying	Total Number Per Cent Control	Legs Before Spraying	Legs After Spraying	Legs Per Cent Control	Body Before Spraying	Body After Spraying	Body Per Cent Control
All 10% in oil										
Butoxypolypropylene glycol 800	7	39	36	8	37	35	5	2	1	50
Butoxypolypropylene glycol 400	9	142	18	87	77	16	79	65	2	97
Iso bornyl thiocyano-acetate	8	65	51	22	49	45	8	16	6	63
Base oil	5	32	40	0	31	34	0	1	6	0
Check	6	25	56	0	22	44	0	3	12	0

[1] Horses No. 5, 6, 7, small piebald cow ponies.
No. 8, Palomino mare.
No. 9, Palomino stallion.

According to this data, butoxypolypropylene glycol *400* appeared to be outstanding in repelling both *Stomoxys* and *Tabanus*, for while the Palomino stallion on which it was applied was attacked by the largest number of flies on July 23, he suffered little attack on July 24. Further trials of this nature will be made to establish definitely the efficacy of this repellent on horses. It might also be noted that the base oil failed to give any protection on horses, although on cows it is frequently somewhat repellent.

Field Tests in Florida.—In 1945, 1946 and 1947, Dr. John T. Creighton conducted considerable work with these materials in Florida using the whole cow method, and two to four animals per treatment. The data from these investigations have not yet been published in full. In essence, it was found that under Florida conditions against horn flies and stable flies on dairy cattle, both butoxypolypropylene glycol *800* and butoxypolypropylene glycol *400* gave several days' protection. In the Gainesville, Florida, area in May 1947, for instance, duration of repellency tests were made using 50 cc. of spray mixture applied over the entire cow. Counts of horn flies were recorded three times daily for a period of 7 days. Butoxypolypropylene glycol *800*, 10 per cent in oil, gave 64 per cent protection based on counts made on the cows prior to treatment. Butoxypolypropylene glycol 400, 10 per cent in oil, gave 73 per cent protection. In this same 7-day period, butoxypolypropylene glycol *800* emulsified 10 per cent in a water base spray reduced fly populations by 57 per cent. It should be emphasized that these protection time figures are the average overall protection for the entire 7-day period. For example, both butoxypolypropylene glycols, each in oil gave over 90 per cent protection during the first 2 days of the test period.

In another series of tests made in April 1947, in the Sarasota, Florida, area, Dr. Creighton attempted to determine the minimum number of sprays required to keep the animals free of flies. The spray was reapplied when any single count (horn flies) was 60 or above. Stable flies were present, but not in adequate numbers. In tests carried on for 16 days, four sprays of butoxypolypropylene glycol *800* at 10 per cent in oil reduced horn fly counts by 83 per cent over the untreated check. The average number of flies per count on the treated cow was 33 as compared with 206 on the untreated check. Five sprays of butoxypolypropylene glycol *400*, 10 per cent in oil, reduced fly populations to 81 per cent of the untreated check.

In general, the protection obtained in

Table 6.—Peet-Grady[1] tests on house flies, *Musca domestica* L., with butoxypolypropylene glycol 800 as activator for pyrethrins.

Mg. Pyrethrins per 100 cc.	Per Cent Activator in Deobase	Total Flies	Per Cent Knock Down 10 Min.	Per Cent Kill 24 Hrs.	OIT Difference	Grade Spray
100 (OTI)[2]	0	651	98.3	57.5	—	B
50	2.5	627	98.1	59.8	+ 2	B
50	5.0	472	98.5	65.8	+ 8	A
50	10.0	465	96.9	78.7	+21	AA
60	10.0	623	98.8	84.1	+26	AA
40	10.0	570	97.2	65.1	+ 7	A
30	10.0	608	97.2	67.6	+10	A
0	10.0	447	59.7	37.6	−22	B−

[1] Peet-Grady official method of the National Association of Insecticide and Disinfectant Manufacturers for evaluating liquid household insecticides.
[2] OTI—Official test insecticide.

these Florida tests was considerable, and extended over a much longer period than was obtained in New Jersey.

PYRETHRUM SYNERGISM.—In laboratory tests with butoxypolypropylene glycol 800, it had been observed that when combined with pyrethrum extract in an oil spray, toxicity of the pryethrum spray was enhanced. Peet-Grady tests confirmed this finding. The data are recorded in table 6. This shows that the use of 10 per cent butoxypolypropylene glycol *800* permits a 40 to 50 per cent reduction in pyrethrum content without loss in knockdown value and an increase in toxicity to make an AA grade household fly spray.

Another experiment using a small quantity of pyrethrum (6.25 mg.) plus varying quantities of butoxypolypropylene glycol *400* (2.5 to 10 per cent) indicates that butoxypolypropylene glycol *400* also possesses activation properties (Table 7), Considerably higher knockdown and kill was obtained as compared with the small quantity of pyrethrins alone.

TOXICOLOGICAL PROPERTIES.—Toxicological studies under the direction of Dr. Henry F. Smyth, Jr. at Mellon Institute have shown that these materials are not hazardous for use on animals or man. Experiments with butoxypolypropylene glycol *800* have indicated that the single dose oral LD_{50} was 9.1 gm. per kg. to rats, and 23.9 gm. per kg. to rabbits. A single dose skin absorption trial of 20 ml. per kg. killed only one of 10 rabbits. A 90 day inunction on rabbits of 1 gm. per kg. per day caused no injury beyond early transient erythema and desquamation. For comparison, DDT has been reported (1948) to have an acute oral toxicity of approximately 0.25 gms. per kg. to rats.

On livestock, no dermatitic effect from either butoxypolypropylene glycol *800* or butoxypolypropylene glycol *400* was observed on such breeds of cattle as Holstein, Ayreshire, Jersey, Brown Swiss and Devon using up to 25 per cent of the materials in a non-toxic oil.

Patch tests on humans conducted by competent toxicologists with undiluted butoxypolypropylene glycol *800* on over 209 subjects showed no primary irritation or sensitization. No irritation was noticed from two to 10 hour applications of undiluted material to face, arms and legs during the course of repeated repellency tests against black flies.[1]

A heating sensation has been observed from production samples of butoxypolypropylene glycol *400* applied directly to human skin at full strength.[2] This was not as noticeable from recently refined samples.

DISCUSSION.—In our early field work, the "half cow" method of testing was adopted because it seemed to offer a means of avoiding differences in susceptibility to fly attack likely to be found among cattle. However, it was also observed that there were fewer flies on the unsprayed side of the sprayed cows than

[1] Undiluted butoxypolypropylene glycol 800 applied to face and arms repelled black flies, *Prosimulium hirtipes* and *Stimulium venustum* (Say), and midges, *Culcoides*, for 2 to 6 hours. Following this repellent period, it did not prevent lighting or crawling of the flies or midges, but it did prevent their biting for an additional 2 to 4 hours.
[2] Mosquito repellency tests during these trials showed that, although the mosquitoes alighted readily, this chemical prevented salt marsh mosquitoes, *Aëdes sollicitans* (Wlkr.), from biting for 3 to 6 hours.

Table 7.—Peet-Grady test on house flies, *Musca domestica* L., with two butoxypolypropylene glycols.

Mg. Pyrethrins per 100 cc. of Spray	Per Cent Activator in Spray	Per Cent Knockdown 10 Min.	Per Cent Kill in 24 Hrs.
Butoxypolypropylene glycol *800*			
6.25	10	79.7	41.8
6.25	5	86.0	47.9
6.25	2.5	76.6	41.6
Butoxypolypropylene glycol *400*			
6.25	10	92.5	51.5
6.25	5	78.4	40.0
6.25	2.5	79.8	39.5
6.25	0	45.5	8.7
100 (OTI)	0	97.6	47.8

on the side of check cow which received no treatment. For this reason, it is felt the "half cow" test gives a minimum repellency figure because more flies would be found on untreated animals. While the tests served the purpose of verifying laboratory results and indicating the relative merit of various materials, these results are in agreement with Fryer *et al.* (1948) in their admirable discussion of the complexity of fly repellent testing, that the whole cow method, where properly handled, is likely to give more reliable information. Where sufficient animals, personnel, and time are available, an arrangement such as they suggest, with due regard for selection of animals, is highly desirable. Much is yet to be learned in this field, especially from the viewpoint of proper design and management of the experiment.

Although the base oil used in oil carried sprays often possesses considerable repellency, especially against horn flies, there is a growing concern about their use. The opinion is often expressed that such sprays exert an adverse physiological effect, particularly on some breeds of cattle. To get away from the possibility of detrimental effects from oil, water-based sprays are being sought. For the most part, such sprays are less repellent and are often difficult to formulate. Some success in this respect, however, is evident from our results with butoxypolypropylene glycol 400 in a water emulsion.

Although we do not know the factors involved, there is evidence from the work of Dr. Creighton and others that protection time can vary considerably. Under Florida conditions, several days protection was obtained as compared to 1 or 2 days when the same materials were tried in New Jersey.

There is often need for fly killing action in addition to repellency. Combinations of butoxypolypropylene glycols with pyrethrins have been made and found compatible from the viewpoint of formulation and effectiveness. In view of the safety of such combinations, they are of especial interest because of increasing findings that DDT, used extensively on cattle, may be absorbed through the skin in harmful quantities.

SUMMARY AND CONCLUSIONS.—Housefly laboratory repellency tests indicated the promise of two butoxypolypropylene glycols, approximate molecular weights 400 and 800. Four years tests on cattle by both "half cow" and whole cow methods conducted in New Jersey and in Florida showed that these materials at 10 per cent concentrations in oil or emulsified in water are stable fly, *Stomoxys calcitrans*, and horn fly, *Siphona irritans*, repellents. Preliminary field tests on horses indicate that they are also repellent to horse flies, *Tabanus* spp. These materials are of further interest in that they possess very low toxicity to mammals, are not irritating, are synergists for pyrethrum and can be formulated readily in oil or water.

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Further Studies on Resistance to DDT in the Housefly[1]

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In a previous paper (Barber & Schmitt 1948) the reactions of a line of houseflies that were resistant to residues of DDT, but were not appreciably resistant to residues of certain other insecticides were described. These flies were called the Ellenville line from the locality in which they had been collected.

This line of flies has been cultured in standard NAIDM larval medium for six months. None of the breeding stock has ever been brought in contact with insecticides and no selection has been practiced in the line. Lately these flies have passed through the 10th and 11th generations, and they were subjected to tests similar to those made in the 1st to 3rd generations to determine whether resistance to DDT had been inherited.

TESTING PROCEDURE.—The flies were tested in the manner described previously by exposure 5 or 6 days after emergence to residues of insecticides applied to plywood squares. The desired residues were obtained by brushing acetone solutions of the insecticides on the surface of the plywood, delivering a known quantity on a measured area. Each experiment consisted of paired hoop-cages of Ellenville and laboratory flies that had been reared by the same methods at the same time, were of the same age, and were exposed at the same time to the same treated surface. After exposure the flies were retained on clean cardboard, they were given milk as food, and records of mortality were taken 24 hours after they had been exposed to the residues.

TESTS WITH DDT AND OTHER INSECTICIDES.—In the tests made during the 1st to 3rd generations of Ellenville flies nine insecticides had been used. In the tests now described eight of these materials were used, of which seven were from the same packages that had been used previously.

DDT (technical).—Eleven tests were made in which flies were exposed to residues at the rate of 144 mgm. of active ingredient per square foot for 15 or 30 minutes or for 1 or 2 hours. The results of these tests are summarised in table 1. Of the 439 flies of the laboratory line exposed to treated surfaces all were killed. Of the 461 flies of the Ellenville line similarly exposed an average of 50.1 per cent were killed.

DDT-pp' (10%).—Eighteen tests were made in which flies were exposed to surfaces to which 144 mgm. of the active ingredient had been applied per square foot for 15 or 30 minutes or for 1, 2, 3, 3.5 or 4 hours. A general summary of the results is given in table 1. Of the 863 flies of the laboratory line exposed to the surfaces 1 survived an exposure of 15 minutes The average rate of mortality was 99.9 per cent. Of the 1218 flies of the Ellen-

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.
[2] Died, Dec. 5, 1948.

Table 1.—Comparison of the rate of mortality of flies of the Ellenville line of the 10th and 11th generations and of flies of the laboratory line of the 33rd and 34th generations when exposed to residues of DDT at a concentration of 144 mgm./sq. ft.

Time Exposed to Residues	Percentages of Flies of the Following Lines Found to Be Dead 24 Hours After Exposure			
	Ellenville		Laboratory	
	Flies tested	Found dead	Flies tested	Found dead
Hours	*Number*	*Per cent*	*Number*	*Per cent*
	DDT (technical)			
¼	82	2.4	89	100.0
½	90	30.0	122	100.0
1	171	56.1	128	100.0
2	118	89.8	100	100.0
	pp' isomer of DDT			
¼	86	7.0	72	98.6
½	166	15.7	199	100.0
1	296	33.4	290	100.0
2	387	59.2	199	100.0
3	51	78.4	57	100.0
3½	189	82.5	—	—
4	43	83.7	46	100.0
	Methoxychlor (technical)			
¼	94	13.8	88	96.6
½	104	49.0	98	99.0
1	88	85.2	67	100.0
2	73	98.6	69	100.0

ville line similarly exposed to treated surfaces an average of 48.6 per cent were killed.

Methoxychlor (technical).—A total of 8 tests were made in which flies were exposed for 15 or 30 minutes or for 1 or 2 hours to surfaces to which 144 mgm. of the active ingredient had been applied per square foot. A summary of the results is given in table 1. Of 322 flies of the laboratory line exposed to the surfaces 3 survived a 15-minute exposure and 1 survived a 30-minute exposure. The average rate of mortality was 98.7 per cent. Of 359 flies of the Ellenville line exposed to to the surfaces the average rate of mortality was 58.8 per cent.

Toxaphene (technical) (chlorinated camphene).—Eight tests were made in which flies were exposed to a surface to which 144 mgm. of the active ingredient had been applied per square foot. When exposed for 30 minutes to a surface five hours after the insecticide had been applied thereto 96.1 per cent of the flies of the laboratory line and 92.8 per cent of Ellenville flies were killed. When exposed for 30 minutes to a similar surface 24 hours after the insecticide had been applied 67.4 per cent of laboratory flies and 72.7 per cent of Ellenville flies were killed. When exposed for 30 minutes to a similar surface four days after the insecticide had been applied 38.9 per cent of laboratory and 42.6 per cent of Ellenville flies were killed. Of 272 flies of the laboratory line exposed for 15 or 30 minutes or 1 hour to residues of this chemical an average of 65.8 per cent were killed, and 69.2 per cent of the 338 flies of the Ellenville line similarly exposed were killed.

Chlordan (technical).—There were five tests were made in which flies were exposed for 2, 5, 10, or 15 minutes to a surface to which 144 mgm. of the active ingredient had been applied per square foot. Of the flies exposed for 2 minutes 97.6 per cent of the laboratory line and 94.9 per cent of the Ellenville line were killed. All flies of each line were killed when exposed for the longer periods to this residue. Of the 210 flies of the laboratory line exposed to this residue an average of 99.5 per cent were killed, and of 208 flies of the Ellenville line similarly exposed 99.0 per cent were killed. Five tests were made in which flies were exposed for 15, 30, or 45 minutes or for 1 or 2 hours to a surface to which 14.4 mgm. of the active ingredient had been applied per square foot. Of a total of 172 flies of the laboratory line exposed to these surfaces an average of 66.9 per cent were killed and an average of 71.1 per cent of 152 flies of the Ellenville line were killed by similar exposures.

Parathion.—Two tests were made in which flies were exposed for 2 or 5 minutes to a surface to which 144 mgm. of the active ingredient had been applied per square foot. One fly of the Ellenville line survived the 2-minute exposure. Of a total of 58 flies of the laboratory line exposed to this surface all were killed, as were 98.9 per cent of the 88 flies of the Ellenville line that were similarly exposed and five more tests were made in which flies were exposed for 5, 10, 15, 30, or 45 minutes to a surface to which 14.4 mgm. of the active ingredient had been applied per square foot. All flies of each line exposed for 10 minutes or longer were killed. When exposed for 5 minutes to this surface 31.7 per cent of flies of the laboratory line and 36.2 per cent of flies of the Ellenville line were killed. Of a total of 163 flies of the laboratory line used in these tests an average of 82.8 per cent were killed, as were an average of 83.8 per cent of a total of 210 flies of the Ellenville line that were similarly exposed.

Gamma Isomer of Benzene Hexachloride.—Two tests were made in which flies were exposed for 2 or 5 minutes to a surface to which 144 mgm. of the active ingredient had been applied per square foot. All of the 82 flies of the laboratory line and all of the 96 flies of the Ellenville line exposed to this residue were killed. In three tests flies were exposed for 10 or 15 minutes to a surface to which 14.4 mgm. of the active ingredient had been applied per square foot. All flies of the laboratory line were killed by these exposures, but one fly of the Ellenville line survived an exposure of 10 minutes. Of a total of 47 flies of the laboratory line exposed to this surface the mortality was 100 per cent, and for a total of 108 flies of the Ellenville line similarly exposed it was 99.8 per cent.

Tetraethyl Pyrophosphate.—There were seven tests made in which flies were exposed for 15, 30, 45 or 60 minutes to a surface to which 144 mgm. of the active ingredient had been applied per square foot. When tested 5 hours after applica-

tion of the insecticide, all flies except a single individual of the laboratory line were killed by exposures of 30 minutes or longer, but exposure to surfaces treated several days before testing gave much less satisfactory kills. Of a total of 253 flies of the laboratory line used in these tests an average of 73.5 per cent were killed, as was an average of 74.1 per cent of a total of 293 flies of the Ellenville line similarly exposed. Three other tests were made in which flies were exposed for 30 minutes or 1 or 2 hours to a surface to which 14.4 mgm. of the active ingredient had been applied 5 hours previously. All flies of each line were killed by the 1 or 2 hour exposures. When exposed for 30 minutes to this surface 89.1 per cent of flies of the laboratory line and 86.8 per cent of flies of the Ellenville line were killed.

Checks.—Flies of each line were exposed to a surface to which acetone had been applied 24 hours previously, or they were held without exposure in the hoop-cages for 24 hours. All flies of each line in these tests survived.

COMPARATIVE EFFECTIVENESS OF RESIDUES OF TECHNICAL DDT FROM DIFFERENT SOURCES.—Flies of the Ellenville line of the tenth and eleventh generations and of the laboratory line of the 33rd and 34th generations were exposed for 30 minutes or for 1 or 2 hours to surfaces of plywood to which each of 8 brands of technical DDT had been applied at the rate of 144 mgm. of the active ingredient per square foot. A summary of the results of these tests is given in table 2. The average rate of mortality of flies of the Ellenville line ranged from 19.4 to 43.0 per cent when exposed to residues of different brands of the insecticide. Similar exposures of flies of the laboratory line resulted in 100 per cent mortality in the case of residues of 6 brands, and few flies survived exposure to residues of two brands. These results indicated that although there appeared to be slight differences in effectiveness in brands of technical DDT, flies of the Ellenville line were highly resistant to all of them. Of 318 flies of the Ellenvilleline exposed to residues of all eight brands for 30 minutes the average rate of mortality was 22.6 per cent, of 333 flies exposed for 1 hour the average rate of mortality was 32.7 per cent, and for 288 flies exposed for 2 hours it was 42.4 per cent.

Table 2.—**Comparison of the percentage mortality of house flies of the Ellenville and laboratory lines exposed for 30 minutes or for 1 or 2 hours to surfaces to which technical DDT of 8 brands had been applied at the rate of 144 mgm./sq. ft.**

BRAND OF DDT	MORTALITY OF FLIES OF THE FOLLOWING LINES 24 HOURS AFTER EXPOSURE TO RESIDUES OF THE STATED BRANDS OF DDT			
	Ellenville		Laboratory	
	Total flies	Found dead	Total flies	Found dead
	Number	*Per cent*	*Number*	*Per cent*
A	125	32.8	91	100.0
B	114	38.6	72	100.0
C	142	28.2	84	100.0
D	148	25.0	71	100.0
E	131	40.5	108	100.0
F	107	43.0	97	100.0
G	93	19.4	95	71.6
H	79	30.4	87	93.1
Total or average	939	32.3	705	95.3

RELATION OF RATE OF MORTALITY OF FLIES OF THE ELLENVILLE LINE TO THE CONTENT OF DDT IN RESIDUES.— Plywood squares were prepared to which technical DDT, the pp′ isomer of DDT or methoxy DDT was applied at concentrations of 1, 2, 3 or 4 mgm. of the active ingredient per square inch. Flies of the Ellenville line were exposed for 15 or 30 minutes or for 1 or 2 hours to these residues. A summary of the results obtained by exposures for 1 or 2 hours is given in table 3. These results indicated that although each of the 3 higher concentrations gave a greater average rate of kill than did the deposit at 1 mgm./sq. in., the 3 and 4 mgm./sq. in. deposits did not result in a higher average rate of kill than resulted from exposures to the deposit of 2 mgm./sq. in. Of a total of 276 flies exposed to residues of all three materials at a concentration of 1 mgm./sq. in. an average of 74.3 per cent were killed, of 194 flies exposed to similar residues at a concentration of 2 mgm./sq. in. an average of 88.1 per cent were killed, of 223 flies exposed to residues at a concentration of 3 mgm./sq. in. 81.6 per cent were killed, and of 309 flies exposed to residues at a concentration of 4 mgm./sq. in, an average of 89.6 per cent were killed. None of the residues gave complete kill of the flies exposed to them for any mentioned length

Table 3.—Comparison of the mortality of flies of the Ellenville line exposed to surfaces bearing residues of DDT at concentrations of from 1 to 4 mgm./sq. in. for 1 or 2 hours.

Concentration of Insecticide in Residue	Mortality of Flies Exposed to Residues of the Following Materials at the Stated Concentrations for 1 or 2 Hours					
	Technical DDT		pp′ isomer of DDT		Nethoxy DDT	
	Total Flies	Found Dead	Total Flies	Found Dead	Total Flies	Found Dead
mgm./sq. in.	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
1	83	56.6	111	75.7	82	91.5
2	56	83.9	46	80.4	92	94.6
3	53	71.7	106	77.4	64	96.9
4	103	78.6	102	97.1	104	93.3

of time. Of a total of 536 flies of the Ellenville line exposed for all mentioned intervals to residues at all concentrations of technical DDT, an average of 59.3 per cent were killed, of a total of 664 flies exposed to similar residues of the pp′ isomer of DDT an average of 72 per cent were killed, and of a total of 641 flies exposed to residues of methoxy DDT an average of 78.8 per cent were killed. In these experiments a total of 573 flies were exposed to residues of all three materials for 15 minutes, 266 were exposed for 30 minutes, 525 were exposed for one hour, and 477 for two hours. The average mortality of the flies was 52.4, 68.4, 78.9, and 88.5 per cent respectively.

Comparison of the Mortality of Flies of the Ellenville Line with that of Two Normal Lines Exposed to Residues of DDT.—Since flies of the Rutgers laboratory line might be suspected of being more than ordinarily susceptible to residues of DDT, puparia of the NAIDM line were obtained from Mr. Frank Nelson of Stanco Inc., for comparison. When they emerged the flies were tested in comparison with flies of the Ellenville and of the laboratory lines of comparable age. Flies of all three lines were exposed to surfaces bearing residues of technical DDT and the pp′ isomer of DDT at concentrations of 1 or 2 mgm./sq. in. for 15 minutes. A summary of the results is given in table 4. These results show that although all of the flies of the laboratory and NAIDM lines were killed when exposed to the residues of each material at each concentration, only from 13.1 to 32.1 per cent of the flies of the Ellenville line were killed by like exposures. These results indicate that flies of the laboratory line are not more susceptible to DDT than are those of another normal line. A further indication that the flies of the laboratory line are relatively normal is the fact that they behave when exposed to DDT residue in the way that experience has shown house flies should react to this insecticide.

Reaction of Flies of the Ellenville Line to Repeated Knock-Down.—That flies of the Ellenville line are capable of surviving repeated knock-down by exposure to residues of DDT was shown in certain experiments. Flies of this line and of the laboratory line were exposed to a residue of the pp′ isomer of DDT at a concentration of 144 mgm./sq. ft. for 30 minutes. This resulted in complete kill of laboratory line flies. After an interval of one hour the Ellenville flies were exposed to the insecticide residue for a second period of 30 minutes, and after another interval of one hour they were exposed for a third period of 30 minutes to the residue. Despite these repeated exposures to DDT residue, only 10 of 53 flies of the Ellen-

Table 4.—Comparison of the mortality of flies of the Ellenville line with that of flies of two normal lines exposed to residues of technical DDT and the pp′ isomer of DDT at concentrations of 1 or 2 mgm./sq. in. for 15 minutes.

Line of Flies	Mortality of Flies of the Stated Lines 24 Hours After Exposure to Residues of the Following Materials			
	Technical DDT		pp′ isomer of DDT	
	Total flies	Found dead	Total flies	Found dead
	Number	*Per cent*	*Number*	*Per cent*
	Residue at the rate of 1 mgm. sq. in.			
Ellenville	106	28.3	109	32.1
NAIDM	85	100.0	111	100.0
Laboratory	98	100.0	121	100.0
	Residue at the rate of 2 mgm. sq. in.			
Ellenville	107	13.1	99	22.2
NAIDM	111	100.0	111	100.0
Laboratory	112	100.0	98	100.0

ville line were killed, or 81.1 per cent survived.

It is probable that when resistant house flies rest on surfaces bearing residues of DDT in buildings or elsewhere, they are knocked down but recover after an interval, and it appears that similar knock-down may be repeated at intervals without causing more than a temporary inactivity of many of them.

DISCUSSION.—The results of testing that have been described show that flies of the Ellenville line, although reared for 10 or 11 generations, or for about six months, under conditions where none of the breeders came into contect with insecticides, had retained resistance to technical DDT, to the pp′ isomer of DDT and to methoxy DDT, but were still not appreciably more resistant to certain other chemicals than were flies ofthe normal laboratory line. In none of the tests made during the first to third or during the tenth and eleventh generations have all of the Ellenville line flies survived exposure to DDT residues. It is probable, as indicated in many of the tests, that the intensity of the resistance factor varied from none to very pronounced among individuals. In each generation the breeders have consisted of an entire colony of flies reared in one jar culture of larval medium. Not only has resistance varied among individuals but it also has varied among the flies of different cultures, probably depending on whether a greater or smaller number of less resistant or more resistant individuals had deposited eggs on a given day when the eggs were used in jar cultures. In general the Ellenville flies were somewhat less resistant to methoxy DDT than to technical DDT or to the pp′ isomer of DDT.

A comparison of the rates of mortality of flies of the Ellenville line exposed to residues of technical DDT shows that the level of resistance was less in the tenth and eleventh generations than it was in the first to third generations. Exposure of flies of this line in the first and second generations to a residue of 200 mgm./sq. ft. for 15 minutes, 30 minutes, 1 hour, and 2 hours resulted in 21.6, 18.6, 66.4, and 86.4 per cent mortality respectively. Exposure of flies of the first and second generations to a residue of 100 mgm./sq. ft. for 15 minutes, 30 minutes, 1 hour and 2 hours resulted in 0.0, 1.3, 28.4, and 43.4 per cent mortality respectivelv. Flies of this line of the third generation exposed to a residue of 144 mgm./sq. ft. for 30 minutes, 1 hour, and 2 hours resulted in mortality of 4.1, 7.4 and 19.8 per cent respectively. Exposure of flies of this line of the tenth and eleventh generations to a residue of 144 mgm./sq. ft. for 15 minutes, 30 minutes, 1 hour, and 2 hours resulted in mortality of 2.4, 30.0, 56.1, and 89.8 per cent respectively.

In the tests described herein, consideration has been given to the suggestions and criticisms that have come to hand in reference to the previous tests. As far as can be determined there was no difference in the behavior of flies of the different lines during their exposure to DDT residues. The only observable difference was that flies of the Ellenville line were knocked down somewhat more slowly than were flies of the normal lines. Experience has shown that those that recovered from the knock-down lived for the usual lengths of time and deposited the usual number of fertile eggs which produced satisfactory cultures of vigorous larvae.

SUMMARY.—House flies of the Ellenville line that had been found to be resistant to residues of technical DDT, to the pp′ isomer of DDT and to methoxy DDT in the first to third generations were tested in the tenth and eleventh generations and were found to be resistant still to these insecticides. As was true of flies of the first to third generations, those of the tenth and eleventh generations were not appreciably more resistant to certain other chemicals than were flies of the normal laboratory line.

Flies of the Ellenville line were highly resistant to each of eight brands of technical DDT.

Although residues of technical DDT, the pp′ isomer of DDT and methoxy DDT were more effective against Ellenville flies at a concentration of 2 mgm./sq. in., than at 1 mgm./sq. in., concentrations of 3 or 4 mgm./sq. in. were not more effective than the 2 mgm./sq. in. residue

Tests using flies of the Ellenville line, the Rutgers laboratory line and NAIDM line showed that the last two were of comparable susceptibility to residues of technical DDT and the pp′ isomer of DDT.

Experiments showed that flies of the Ellenville line could survive repeated knock-down by DDT residues.

Although flies of the Ellenville line in the 10th and 11th generations were less resistant on average to residues of DDT than they had been found to be when in the 1st to 3rd generations, they still were highly resistant to residues of this insecticide. Those that survived exposure to the DDT residues lived for the usual lengths of time and deposited the usual number of fertile eggs which produced satisfactory cultures of vigorous larvae.

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Species-Specificity of Toxicants as Related to Route of Administration

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It is common knowledge that insect species differ in their susceptibilities to different insecticides. Also, there is ample evidence that the response to a toxicant may differ considerably depending upon the route of administration (for reviews, see particularly Hoskins, 1940; Menusan, 1948; Heal & Menusan, 1948). It is not so clear whether this species-specificity is related in any way to route of administration, or whether a compound may be inherently toxic to all species, but fails to reach directly or indirectly the site of action in those insects thought to be resistant. In touching upon this problem, Dresden & Krijgsman (1948) concluded that DDT and benzene hexachloride, because of their similarities in toxicity upon injection and upon external application, were general poisons, and that the several isomers of benzene hexachloride differed in killing power because of inherent differences in toxicity and not because of different powers of penetration. Menusan (1948) and Heal & Menusan (1948) discussed the relative susceptibilities of insects to insecticides and the differences associated with route of administration but did not interrelate the two aspects of the problem. Turner *et al.* (1948) in a study of nicotinium compounds administered by injection and by spraying divided the chemicals into groups of those with superior penetrating power but inferior toxicity, those with high toxicity but poor penetrating power, and those with low toxicity and fair penetrating power. In this study, however, the two methods of application were made to different species of insects.

The approach here reported involved the treatment of four insect species with five toxicants by four routes of administration. The insects used were worker honeybees, *Apis mellifera* L., adult milkweed bugs *Oncopeltus fasciatus* (Dall.), Japanese beetle grubs *Popillia japonica* Newm., and wax moth larvae, *Galleria mellonella* L. All these could be reared or maintained readily in the laboratory and could be expected to respond variously to toxicants because of their physiological differences. The toxicants used, representing different types of action, were nicotine, arsenic, DDT, parathion, and ethylene dichloride. The routes of administration employed were parenteral, enteral, topical, and inhalation.

MATERIALS AND METHODS.—For use honeybees were taken directly from either regular beehives or from observation hives. For the most part field bees were used, newly emerged bees being avoided. After treatment the bees were retained in cloth-covered beakers and provided with water, held in dental-wick-stoppered vials, and candy, made with honey and confectioners' sugar held in open gelatin capsules.

The large milkweed bug was reared by methods similar to those of Worthley in Campbell & Moulton (1943). Callow adults were avoided, but bugs in a group were used before oviposition had begun. Following treatment these were kept in cloth-covered beakers and supplied with milkweed seed and vials of water.

Third-instar grubs of the Japanese beetle were collected in the field and held in cold storage at 40° F. A few days prior

to treatment the grubs were brought to room temperature and allowed to feed on sprouting grass. Grubs tested, therefore, were in active feeding condition. After treatment the grubs were placed in soil in ointment jars and provided with sprouting grass for food.

The wax moth was reared on a medium composed of infant food[1] and pulverized dog meal moistened with honey. A small amount of old honeycomb was usually provided to stimulate oviposition by the moths introduced into the rearing jars. Large larvae were used in testing, but they were not standardized either by age or by instar. After treatment the larvae were kept in ointment jars containing adequate food medium.

Water was the only solvent used for nicotine and arsenic (and for parathion in bee-feeding tests), and olive oil was the only solvent used for DDT, ethylene dichloride, and parathion. No adjuvants of any kind were used except in the feeding tests with honeybees, in which a 50 per cent honey-water solution served as the vehicle. The nicotine used was in the form of the free base, and the arsenic was in the form of sodium metarsenite. The technical grades of parathion[2] and ethylene dichloride were used. Pure p, p′-DDT was used except for feeding tests with bees in which a finely prepared technical grade[3] was required for uniform suspension in the honey-water feeding mixture.

An injection device for delivering dosages of one microliter, controlled by the use of a micrometer-screw arrangement, utilized a one cc. tuberculin syringe with a 30-gauge or 27-gauge hypodermic needle. This was used for parenteral injection in all the insects. Parenteral injection implies that technique which is variously reported as body-cavity injection, blood stream injection, sub-cutaneous injection, and intra-abdominal injection. In all four species of insect the point of injection was in the abdominal region. The same device was used for applying the materials topically to the external integument. On the milkweed bugs the toxicants were applied to the dorsal surface of the abdomen beneath the wings. On the honeybee, the materials were applied to the peduncle, thus covering the anterior region of the abdomen and usually coming into contact with the wings. On the Japanese beetle grubs and wax moth larvae application was made to the ventral thorax between the legs and out of reach of the mouth parts. Enteral injection in wax moth larvae and Japanese beetle grubs was made by using a blunt 30-gauge needle with the injection apparatus. In effect, the needle could be slipped into the buccal cavity and esophagus with comparative ease and no injury to the insect. The exact region of application in the alimentary tract was not determined, but placement was deep enough to avoid immediate regurgitation. For enteral administration to honeybees, individual feeding was accomplished by permitting bees separately contained in glass tubes to drink from the tip of a .2 ml. capillary pipette (graduated in increments of .01 ml.) containing a 50 per cent honey-water solution with the toxicant added. The amount of fluid consumed at a single feeding served as the basis for calculating dosage. Exposure to the toxicant by inhalation (*i.e.*, fumigation) was made by placing the test insects in a closed system in which the contained air was saturated by bubbling through the toxicant (Fig. 1). Air movement was induced by pumping the rubber bulb in the system. Pumping was continuous during short exposures, but during longer exposures, pumping was intermittent after an initial 3-minute period. Three strokes of the "pump" were sufficient to displace as much air as

[1] *Pablum.*
[2] Supplied by the American Cyanamid Co.
[3] *Penlech A*, supplied by the Pennsylvania Salt Manufacturing Co.

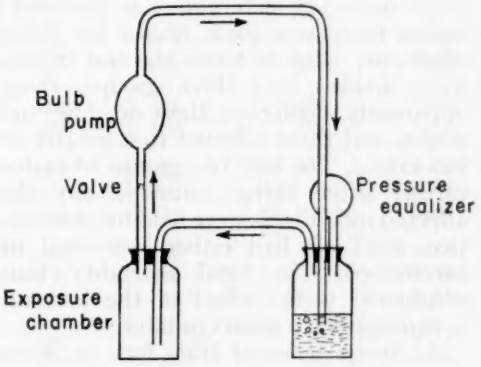

FIG. 1.—Device for exposing insects to air saturated with vapor of the toxicant. Arrows indicate direction of air flow.

the system contained, so it is believed that saturation of the air with the vapor of the toxicant was rapidly achieved. A toy rubber balloon served as the pressure equalizer.

It was not practicable to secure data on all possible combinations of the three variables (insect-toxicant-route). For example enteral administration was not possible for any toxicant with the milkweed bug because its mouth parts do not permit injection, and it does not voluntarily feed on the toxicants as formulated. Honeybees would not feed on honey to which nicotine was added in lethal concentrations, and ethylene dichloride was not miscible with honey-water solutions. With the method of testing, arsenic and DDT could not be vaporized to permit inhalation exposures. These omissions do not detract seriously from the advantage of using similar techniques and formulations throughout the experiment.

All tests were made in a constant temperature room maintained at 76° F., and prior to injection the insects were anesthetized with carbon dioxide. Although dosages were not adjusted to the weights of individual insects, each test group was weighed and the average used to calculate the dosages in terms of milligrams of toxicant per kilogram body weight for all routes of administration except inhalation, in which the time of exposure in seconds was the dosage factor. Uniform volumes of one microliter were administered except in those cases where toxicity was so low as to require the use of larger volumes of concentrated material to achieve the desired dosage.

The criterion of toxic action was endpoint mortality determined in this way: unless there was some reason for doing otherwise, after 48 hours the test insects were divided into three groups—those apparently unaffected, those dead beyond doubt, and those affected to a greater or less extent. The first two groups were discarded after being counted, but the affected individuals were held for observation until all had either recovered or succumbed. The total mortality thus considered is the effect of the toxicant in causing death sooner or later.

A dosage series of from four to seven concentrations was used in each test which was repeated from three to nine times depending upon how definite the trend appeared. Within a single test, from 10 to 20 individuals were treated with each concentration. With some few exceptions, weights and corrected probits were used in the log-probit transformation for calculating the dosage-response curves (Bliss, 1935). To be sure, not all curves were equally satisfactory from a statistical point of view, but it is believed that the poorer fitting curves are associated with greater variability in response to a particular combination of toxicant, route, and insect than with the technique employed or the variation between groups of individuals. For instance, although five tests were made of topical application of arsenic to honeybees, with dosages ranging from .17 to 95.5 mg./kg., no trend was established either with individual tests or combined data. Mortality of some groups was high, but this bore no apparent relation to dose or natural mortality. (A possible explanation of this is given below.) On the other hand parenteral injection of arsenic and topical application of DDT yielded excellent curves with honeybees, and topical application of arsenic to milkweed bugs resulted in good dosage-response. In other words, the variation, greater than the biological variation usually encountered, did not seem to be due to the toxicant alone, the technique alone, nor to the insect alone, but to the complex of all three. It is very possible that this variation is actually the result of trying to make several compound curves, which are out of phase with each other, conform to the accepted dosage-response curve. Such a possibility was discussed by Turner (1945) in a different type of study. It is known definitely that one sort of compound curve was obscured by using extra replicates. This is being reported elsewhere (Beard 1949), but it involved the enteral administration of parathion to Japanese beetle grubs. It was found that higher dosages had a purgative action rapid enough to eliminate the toxicant in lethal concentrations.

For the most part mortality was negligible among control insects treated with water or olive oil without toxicants. When this mortality was appreciable, the test data were discarded. As a further check on technique, the dosage series was usually chosen to be broad enough to produce results ranging from no mortality to no survivors.

Table 1.—Data from calculated dosage-response curves for each toxicant applied by each route to each insect.

INSECT	TOXICANT	ROUTE	NUMBER OF INSECTS USED	LD_{50}[1]	LD_{95}[1]	SLOPE
Honeybee	Arsenic	Parenteral	519	.8	4.6	2.26
		Enteral	160	.0046[2]	.0049[2]	
		Topical	302	?	?	?
	DDT	Parenteral	536	.2	400	.39
		Enteral	199	1.7	14.6	1.51
		Topical	188	114	224	5.60
	Ethylene dichloride	Parenteral	371	2,353	11,370	2.40
		Topical	371	40,160	105,100	3.93
		Inhalation	388	48	123	4.02
	Nicotine	Parenteral	261	52	37,834	.57
		Topical	245	315	935	3.41
		Inhalation	252	708	7,320	1.62
	Parathion	Parenteral	228	.94	3.47	2.91
		Enteral	108	.08	.2	3.89
		Topical	272	1.47	1.67	30.36
		Inhalation	433	?[3]	?[3]	
			4,833			
Japanese beetle grubs	Arsenic	Parenteral	249	6.6	34	2.69
		Enteral	205	9.8	28.6	3.54
		Topical	35	(1,721)+[4]	+	
	DDT	Parenteral	294	162	679	2.65
		Enteral	293	205	1,120	2.23
		Topical	240	93	549	2.12
	Ethylene dichloride	Parenteral	349	2,400	27,800	1.55
		Enteral	280	3,669	59,650	1.36
		Topical	116	21,460	126,800	2.15
		Inhalation	323	32	306	1.68
	Nicotine	Parenteral	599	738	847,390	.54
		Enteral	631	532	31,900	.93
		Topical	253	890	15,150	1.34
		Inhalation	312	(25,200)+	+	
	Parathion	Parenteral	240	.448	5.79	1.48
		Enteral	333	4.51	23.0	2.32
		Topical	164	3.3	27.8	1.78
		Inhalation	347	?[3]	?[3]	
			5,263			
Milkweed bugs	Arsenic	Parenteral	378	3.4	8.8	3.99
		Topical	253	88	879	1.65
	DDT	Parenteral	226	301	1,966	2.02
		Topical	498	409	8,280	1.26
	Ethylene dichloride	Parenteral	302	36,000	827,000	1.21
		Topical	428	208,000	575,300	3.72
		Inhalation	496	3,270	28,974	1.74
	Nicotine	Parentera	299	36	407	1.56
		Topical	344	105	292	3.70
		Inhalation	561	43	146	3.11
	Parathion	Parenteral	208	8.39	28.3	3.11
		Topical	192	47	140	3.48
		Inhalation	382	?[3]	?[3]	
			4,567			

Table 1. (*Continued*)

Insect	Toxicant	Route	Number of Insects Used	LD_{50}[1]	LD_{95}[1]	Slope
Wax moth larvae	Arsenic	Parenteral	403	7.5	9.2	7.54
		Enteral	363	8.9	17.5	5.61
		Topical	166	(3,014)+	+	
	DDT	Parenteral	277	74.2	210	3.64
		Enteral	239	151	991	2.02
		Topical	105	(834)+	+	
	Ethylene dichloride	Parenteral	288	3,081	24,320	1.83
		Enteral	204	12,220	441,300	1.06
		Topical	60	(76,740)+	+	
		Inhalation	329	3,480	24,210	1.95
	Nicotine	Parenteral	295	843	3,818	2.51
		Enteral	380	742	6,972	1.69
		Topical	341	22,800	584,000	1.17
		Inhalation	229	(28,800)+	+	
	Parathion	Parenteral	408	91.1	3,706	1.02
		Enteral	308	125	532	2.61
		Topical	256	2,215	24,200	1.58
		Inhalation	100	(57,600)+	+	
			4,751			

[1] The values given for inhalation tests are in terms of time of exposure, in seconds. All other values are in terms of milligrams of toxicant per kilogram of body weight.

[2] The values for enteral administration of arsenic to honeybees were not calculated, but were based on a well-defined response o complete survival of bees receiving .0043 mg./kg. or less, and complete mortality of bees receiving .0049 mg./kg. or more.

[3] Data are not given for these tests on inhalation of parathion because the test results were not reproducible. Two samples of parathion were employed in these tests and it was not determined whether these samples varied in their vapor toxicity or whether the condition of the insects at time of testing was responsible. In some cases, even momentary exposure of bees to the vapor killed all individuals. In others, bees withstood 15 minutes' exposure or more. In decreasing order of susceptibility were honeybees, Japanese beetle grubs, milkweed bugs, and wax moth larvae, but the magnitude of the differences was not satisfactorily estimated.

[4] In the cases thus indicated (+), the LD_{95} and consequently the LD_{95} exceeded the maximum measurable dosage, which is given in parenthesis. Higher dosages were precluded by the limited solubilities of the toxicants or by removal due to run-off or to contact with other surfaces. For the most part these apply to topical application or inhalation and indicate, in effect, lack of toxicity by these routes. For example wax moth larvae survived momentary immersion in 100% ethylene dichloride, and some even survived similar immersion in olive oil containing 8% DDT. In general the run-off point marked the maximum measurable dose for topical application, and for inhalation it seemed unnecessary to continue exposures longer than seven or eight hours.

RESULTS.—The calculated data obtained from these tests are given in table 1. It should be realized that some of the high values given were obtained by extrapolation of the calculated curve and that such dosages might be impossible to administer. No attempt has been made to relate the data to those obtained by other workers because of the primary interest in basing comparisons upon values obtained by the use of uniform techniques.

DISCUSSION.—Several individual items of data warrant comment.

As will be indicated below, arsenic is the most toxic of the chemicals tested. When applied topically, however, it was toxic only to the milkweed bug and the honeybee. In the milkweed bug it produced, at certain dosages, a peculiar and characteristic paralysis of the hind legs. The penetration of arsenic through the integument of insects has received considerable study (Hoskins, *loc. cit.*). Just why arsenic penetrates the integument of the milkweed bug and the honeybee but not that of the Japanese beetle grub and the wax moth larva has not been critically studied, but it is suggested that possibly penetration occurred in the wings, the toxicant then being transported by way of the wing circulation. In the milkweed bug the toxicant was placed in intimate contact with the wings; in the honeybee, placement on the peduncle permitted contact with the wings in some cases and not in others. This could explain the lack of regularity in response by the honeybee.

Comparing the data for parenteral injection and topical application as a measure of penetrability, nicotine was as consistent a penetrant as the other compounds. On this basis the penetration of DDT in honeybees was of a low order as

compared with other insects, and in Japanese beetle grubs DDT was actually more toxic by topical application than by parenteral injection.

The extent to which death following topical application was actually due to fumigant action is not clear, but probably this was true with ethylene dichloride. The toxicity of this by topical application was so low that in some cases the insect needed to be covered entirely by the chemical before death resulted, possibly from fumigant action in view of the relatively high vapor toxicity. With nicotine and parathion the high toxicity of topical application relative to vapor toxicity would tend to indicate the absence of much fumigant action.

The high vapor toxicity of ethylene dichloride as compared with that applied by parenteral injection in Japanese beetle grubs indicates that fumigant action may be as fundamental in action at the cellular level as when the toxicant is present in the hemolymph.

The very high toxicity of arsenic to bees by feeding as compared with parenteral injection should be noted.

Also very striking is the high resistance of the wax moth larva to all insecticides administered topically.

The very flat slope, resulting in the high value for the LD_{95}, in the response of honeybees to the parenteral injection of nicotine seems remarkable, but this is one of those cases mentioned above in which the variation about the fitted line was excessive.

RELATIVE SUSCEPTIBILITY OF INSECTS TO TOXICANTS BY EACH ROUTE.—A comparison of the LD_{50} values makes possible the ranking of the four insects according to their susceptibility to each toxicant by each route of administration. In decreasing order of susceptibility the insects are listed in table 2. The most consistent response here indicated is the greater resistance on the part of the wax moth larva. It is clearly evident that the different routes do not rank the insects in the same order of susceptibility. Out of 24 possible comparisons between any two routes for each toxicant, only five rank the insects in the same order, and only one combination of three (parenteral, topical, and inhalation for nicotine) ranks the insects in the same order of susceptibility.

RELATIVE SUSCEPTIBILITY OF INSECTS TO TOXICANTS BY MOST EFFECTIVE ROUTE.—It has been considered that variation in response is due not to differences in inherent toxicity, but to the relative ease with which the toxicant reaches the site of action. If this is true, the susceptibility of an insect to a compound *when administered by the most effective route* should serve as an index to the inherent toxicity of that compound. Table 3 illustrates such a comparison of toxicities, that is, the relative susceptibilities of the insects by the most effective route of administration, based upon the LD_{50} values referred to that of the most susceptible insect being one.

It is obvious that important differences do exist, not only in the ranking order of the insect species, but in the magnitude of the differences. Nicotine, in which the differences are only about 20-fold, would seem to be less specific than DDT or arsenic, in which the differences are several hundred-fold. As ordinarily considered, ethy-

Table 2.—Susceptibility of insects to toxicants administered by each route, based upon LD_{50} values.

ROUTE	TOXICANT	ORDER OF SUSCEPTIBILITY
Parenteral	Arsenic	Bee >Bug >Grub >Larva
	DDT	Bee >Larva >Grub >Bug
	Ethylene dichloride	Bee >Grub >Larva >Bug
	Nicotine	Bug >Bee >Grub >Larva
	Parathion	Grub >Bee >Bug >Larva
Enteral	Arsenic	Bee >Larva >Grub
	DDT	Bee >Larva >Grub
	Ethylene dichloride	Grub >Larva
	Nicotine	Grub >Larva
	Parathion	Grub >Larva >Bee
Topical	Arsenic	Bug >Bee
	DDT	Grub >Bee >Bug >Larva
	Ethylene dichloride	Grub >Bee >Larva >Bug
	Nicotine	Bug >Bee >Grub >Larva
	Parathion	Bee >Grub >Bug >Larva
Inhalation	Ethylene dichloride	Grub >Bee >Bug >Larva
	Nicotine	Bug >Bee >Grub >Larva
	Parathion	Bee >Grub >Bug >Larva

Table 3.—Relative susceptibility of insects to toxicants administered by most effective route, based upon LD_{50} values; most susceptible = 1.

Arsenic	Bee	Bug	Grub	Larva
	1	739	1435	1630
DDT	Bee	Larva	Grub	Bug
	1	371	465	1505
Ethylene dichloride	Grub	Bug	Bug	Larva
	1	1.5	102	109
Nicotine	Bug	Bee	Grub	Larva
	1	1.4	15	21
Parathion	Bee	Grub	Bug	Larva
	1	5.6	105	1139

Table 4.—Relative susceptibility of insects to toxidants administered by most effective route, based on LD_{95} values; most susceptible = 1.

Arsenic	Bee	Bug	Larva	Grub
	1	1.9	2	6.2
DDT	Bee	Larva	grub	Bug
	1	14	38	135
Ethylene dichloride	Bee	Grub	Larva	Bug
	1	2.5	197	236
Nicotine	Bug	Bee	Larva	Grub
	1	6.4	26	104
Parathion	Bee	Grub	Bug	Larva
	1	29	142	2660

lene dichloride would be the most specific because it was toxic only as a fumigant against two of the four species. In terms of relative susceptibility by the most effective route, however, it, too, is somewhat less specific than DDT and arsenic. These data would imply that there is real species-specificity, although it must be realized that a given route of administration does not necessarily place the toxicant at the site of action. There may be cell and tissue boundaries that serve as important barriers to the transport of the toxicant to the sensitive substrate. By changing the route of administration the grosser barriers of the integument, gut wall, or tracheal wall, as the case may be, can be circumvented, thus bringing the toxicant at least one degree nearer the site of action. The above data demonstrate, however, that species-specificity is only partially overcome by changing the route of administration. Consequently, until more is known about the mode of action and the site of action at the cellular level, it can be concluded that a compound toxic to one insect does not necessarily possess inherent toxicity to other insects. Undoubtedly, quantitative differences in the sensitive substrate or other physiological variables are responsible for a real species-specificity.

Comparisons are more precise at the 50 per cent level, but there is some interest in the LD_{95} because of the practical control aspect, even though it is recognized that with some curves this represents an extrapolation of the data. Because of pronounced differences in slopes of some of the curves the most effective route at the 50 per cent level may not be the same as at the 95 per cent level, and also the slopes of some curves for the same route in different insects differ.

Table 5.—Ranking order of insects in specificity of response as indicated by slope of dosage-response curve, based upon route of administration giving steepest curve.

Arsenic	Bee > Larva > Bug > Grub
DDT	Bee > Larva > Grub > Bug
Ethylene dichloride	Bee > Bug > Grub > Larva
Nicotine	Bug > Bee > Larva > Grub
Parathion	Bee > Bug > Larva > Grub

Consequently, the ranking order of insect susceptibility, based upon the LD_{95} for the most effective route of administration, may be different from that based upon the LD_{50} as can be seen in table 4. At this level, too, no two insecticides rank the insects in the same order of susceptibility, but it will be seen that the magnitude of the differences is, in general, less than that indicated in table 3. This latter implies that when insecticides are tested at higher dosage levels only, they might appear to be less species-specific. A striking difference in the above comparisons is that at the 95 per cent level, arsenic appears to be much less species-specific than nicotine.

In view of the fact that the dosage-mortality curve is descriptive of the variation in susceptibility among the individuals of a population and that a steep slope implies more uniformity of response, a comparison of slopes of the curves is another measure of species-specificity of a toxicant. Table 5 shows the ranking order of insects in terms of steepness of slope, based upon the route of administration giving the steepest dosage-response curve. Again the order of insects is not the same for any two insecticides, but the honeybee appears to be more specific in its response than do the other insects tested.

RELATIVE EFFECTIVENESS OF ROUTES OF ADMINISTRATION.—Reference to table 1 will indicate the magnitude of the differences in effectiveness between routes of administration, but the relative order of effectiveness of the routes in relation to each insect for each insecticide is given in table 6. This comparison indicates that in 12 out of 20 possibilities, parenteral administration was more effective than other routes. While this permits the conclusion that chemicals placed in contact with the coelomic tissues are more likely to demonstrate their effectiveness than when placed in contact with other tissues, there are sufficient exceptions to suggest

Table 6.—Order of effectiveness of routes of administration.[1] Based upon LD_{50} values.

INSECT	TOXICANT	ROUTE, IN ORDER OF EFFECTIVENESS
Honeybee	Arsenic	Enteral > Parenteral > Topical
	DDT	Parenteral > Enteral > Topical
	Ethylene dichloride	Inhalation > Parenteral > Topical
	Nicotine	Parenteral > Topical > Inhalation
	Parathion	Inhalation (?) Enteral > Parenteral > Topical
Japanese beetle grub	Arsenic	Parenteral(=)[2]Enteral > Topical
	DDT	Topical > Parenteral > Enteral
	Ethylene dichloride	Inhalation > Parenteral > Enteral > Topical
	Nicotine	Enteral > Parenteral > Topical > Inhalation
	Parathion	Parenteral > Topical (=)Enteral > Inhalation (?)
Milkweed bug	Arsenic	Parenteral > Topical
	DDT	Parenteral > Topical
	Ethylene dichloride	Inhalation > Parenteral > Topical
	Nicotine	Parenteral(=)Inhalation > Topical
	Paration	Parenteral > Topical > Inhalation (?)
Wax moth larvae	Arsenic	Parenteral(=)Enteral > Topical
	DDT	Parenteral > Enteral > Topical
	Ethylene dichloride	Parenteral(=)Inhalation > Enteral > Topical
	Nicotine	Enteral (=)Parenteral > Topical > Inhalation
	Parathion	Parenteral > Enteral > Topical > Inhalation (?)

[1] The ranking of the inhalation values, which are expressed in terms of time of exposure, with the other values, which are expressed in terms of mg./kg., may be questioned, but in most cases the differences were sufficiently great to permit placement without much doubt.

[2] (=) The routes thus indicated appear to be sub-equal.

caution in interpreting results based only on parenteral injection of unknown compounds.

RELATIVE TOXICITY OF INSECTICIDES BY EACH ROUTE.—A comparison of the LD_{50} values makes possible the ranking of the five insecticides according to their toxicity to each insect by each route of administration. In decreasing order of toxicity the insecticides are listed in table 7. The most consistent response here indicated is the lack of toxicity of ethylene dichloride by all routes of administration except inhalation, by which it is generally more toxic than the other compounds. Also by topical application, parathion is uniformly more toxic than the others. With these exceptions, there is considerable variation in the ranking order of the toxicities as measured by the response of the different insects.

RELATIVE TOXICITY OF INSECTICIDES ADMINISTERED BY THE MOST EFFECTIVE ROUTE.—The inherent toxicities of the several insecticides can be compared better if they are considered in terms of their most effective routes respectively. Such a comparison is shown in table 8. The toxicities are based upon LD_{50} values, referring them to the most toxic as being one. These data imply that of the insects studied, the honeybee is the most selec-

Table 7.—Toxicity of insecticides administered by each route, based upon LD_{50} values.

ROUTE	INSECT	ORDER OF TOXICITY				
Parenteral	Honeybee	DDT	Arsenic	Parathion	Nicotine	Ethylene dichloride
	Japanese beetle grub	Parathion	Arsenic	DDT	Nicotine	Ethylene dichloride
	Milkweed bug	Arsenic	Paration	Nicotine	DDT	Ethylene dichloride
	Wax moth larvae	Arsenic	DDT	Parathion	Nicotine	Ethylene dichlorine
Enteral	Honeybee	Arsenic	Parathion	DDT		
	Japanese beetle grub	Parathion	Arsenic	DDT	Nicotine	Ethylene dichloride
	Wax moth larvae	Arsenic	Parathion	DDT	Nicotine	Ethylene dichloride
Topical	Honeybee	Parathion	Arsenic?	DDT	Nicotine	Ethylene dichloride
	Japanese beetle grub	Parathion	DDT	Nicotine	Ethylene dichloride	Arsenic
	Milkweed bug	Parathion	Arsenic	DDT	Nicotine	Ethylene dichloride
	Wax moth larvae	Parathion	Nicotine	DDT?	Arsenic?	Ethylene dichloride?
Inhalation	Honeybee	Ethylene dichloride	Parathion?	Nicotine		
	Japanese beetle grub	Ethylene dichloride	Parathion?	Nicotine		
	Milkweed bug	Nicotine	Ethylene dichloride	Parathion		
	Wax moth larvae	Ethylene dichloride	Nicotine	Parathion		

Table 8.—Relative toxicity of insecticides administered by most effective route, based upon LD_{50} values; most toxic = 1.

Honeybee	Arsenic 1	Parathion 17	DDT 43	Ethylene dichloride 10,435	Nicotine 11,304
Japanese beetle grub	Parathion 1	Arsenic 15	Ethylene dichloride 71	DDT 208	Nicotine 1,188
Milkweed bug	Arsenic 1	Parathion 2	Nicotine 11	DDT 89	Ethylene dichloride 962
Wax moth larvae	Arsenic 1	DDT 10	Parathion 12	Nicotine 99	Ethylene dichloride 411

tive, and the milkweed bug and wax moth larva are the least selective in differentiating the toxicities among compounds. Of chief significance, however, is the fact that no two insects rank these insecticides in the same order of toxicity when the administration by the most effective route is the basis of comparison.

The data and comparisons presented above may find direct application in the execution and interpretation of screening programs, but they may also lead to a better understanding of toxicological phenomena. The fact that the most effective route for a compound in one insect may be different in another insect is just one item that emphasizes physiological differences among species. It appears that the inherent toxicity of chemical compounds may be less important than is commonly believed, and that there is a greater need for the study of the sensitive substrates among insect species in terms of specific toxic actions. If, as suggested by these observations, each insect species responds in its own characteristic toxicity pattern, just as each organic chemical has its characteristic infra-red absorption spectra, it may be that advantage can be taken of this specificity in studying insect physiology and the mode of toxic action manifested in a series of chemicals.

SUMMARY.—Toxicological tests involving five insecticides applied to four insect species by four routes indicate that species specificity is definite and is only partially overcome by changing the route of administration of the toxicant. Compared on the basis of the most effective route of administration, no two of the insecticides tested rank the insects in the same order of susceptibility. These observations are of concern in exploring the possible usefulness of promising insecticides.

Although the insecticides tested do not rank the routes of administration in the same order of effectiveness, parenteral injection was generally the most effective route. This gives support to the recent trend toward using this technique in screening programs, but there were sufficient exceptions to suggest caution in interpreting results based on this method alone.

Of the insects studied, no two species ranked the insecticides in the same order of toxicity as based on the most effective route of administration. This is of concern in those studies using one or few species of insect in the evaluation of candidate compounds for insecticidal purposes.

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Preliminary Field Tests Using a Polyhedrosis Virus to Control the Alfalfa Caterpillar[1]

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For the past 40 years, populations of the alfalfa caterpillar, *Colias philodice eurytheme* Bdvl., have been observed to be greatly reduced by the natural occurrence of epizootic disease. In recent years, it has become known that most of these epizootics are caused by a polyhedrosis virus —*i.e.*, a virus which causes the formation of polyhedral inclusion bodies in the nuclei of cells of the infected tissues (Steinhaus, 1948). Although the effect of these natural outbreaks of disease has been of considerable value in reducing destructive alfalfa-caterpillar populations, unfortunately the effects of such epizootics often occur so late in the larval life of the insect population that most of the damage to the crop has already occurred by the time the caterpillars are destroyed by the virus.

During the course of our studies on the etiology and epizootiology of the disease, the possibility of initiating the epizootic earlier than it begins naturally was postulated. Since, except for a superficial effort in South Africa (Lounsbury, 1913), the literature contains no account of an attempt to use a virus disease in the control of a crop pest, there was no reliable assurance that the artificial distribution of the virus could be conducted in a manner which would reduce the population of the caterpillar to a point below that of economic importance. Furthermore, no satisfactory data were available as to whether or not an epizootic could be initiated in populations of relatively low densities, since natural epizootics are most apparent at times of high population densities.

Before conducting extensive field tests for the purpose of obtaining information on these questions, it was decided to carry out a few preliminary experiments of a purely exploratory nature. This was accomplished during the summer of 1948. The results of these cursory tests were so encouraging that it seemed pertinent to report them at this time even though they should be considered as indicative only and by no means conclusive.

PREPARATION OF VIRUS MATERIAL.—Since a method of cultivating viruses on artificial culture media has not yet been devised, it was necessary to find other means of producing the agent of alfalfa-caterpillar polyhedrosis in quantities great enough to be used for distribution in the field. Furthermore, as far as has been demonstrated, only the alfalfa caterpillar is susceptible to the particular virus with which we are concerned. Therefore, the only practical method of producing the virus was by infecting alfalfa caterpillars, permitting the virus to increase in their tissues, and then gathering and processing their infected bodies.

Although it would be feasible to rear the *Colias* larvae in large numbers in the insectary, and then to infect them, for the experiments herein reported it was found more convenient to gather the caterpillars from naturally infested fields. They were brought into the laboratory and placed within large barriers or rearing trays, where they were crowded together with previously infected individuals. In a few days nearly all were dead or dying from the polyhedrosis. Their infected bodies were collected periodically, placed in large glass vials, and then held in the refrigerator until needed.

In preparing the infectious material for field distribution the larvae, which for the most part had undergone disintegration and were in a semi-fluid condition, were triturated to a thick homogenous suspension in a Waring blendor. The material was then diluted 1:3 with distilled water, passed through cheesecloth to remove large particles, and a hemacytometer count made of the approximate number of polyhedral bodies in the suspension. Since there is undoubtedly some free virus (*i.e.*, virus not included in the polyhedral bodies) in such a suspension, the use of polyhedral counts to ascertain the concentration of virus activity is probably open to error and only approximates the amount of virus present. Nevertheless, the polyhedral count is a

[1] Contribution from the Laboratory of Insect Pathology, Division of Biological Control, College of Agiculture, University of California, Berkeley.

[2] The authors wish to thank Dr. Ray F. Smith for valuable suggestions made during the course of this investigation.

convenient means of arriving at this approximation.

The concentrated infectious material was taken into the field and then further diluted so that the polyhedral count of the final spray solution was between 50,000,000 and 100,000,000 per ml. the final dilution being determined by calculation from the earlier hemacytometer count. To apply the spray, an ordinary 5-gallon back-pack hand sprayer was used. The spray was directed uniformly over the alfalfa.

RESULTS OF FIELD TESTS.—During the summer of 1948, in order to ascertain the possible practical value of distributing the virus artificially, four separate tests were conducted on plots situated in alfalfa fields in central California in the Westley-Patterson area (northwest portion of the San Joaquin Valley). Comparable plots in the same fields were established as untreated controls. In all cases, the end of the experiment was dictated by the cutting of the field by the grower. The gross data obtained during these tests are given in the accompanying table and graphs. The pertinent information pertaining to each plot is as follows:

Plot 1.—The size of test plot 1 was 20 by 400 feet; that of the control plot was the same. One gallon of virus suspension (97,000,000 polyhedra per ml.) was applied to the alfalfa in this plot. As shown in table 1 and figure 1, the population of 58 larvae per 10 sweeps at the time of application of the virus rose to 154 per 10 sweeps in the control plot in 15 days. In the plot treated with virus suspension, the larval count remained parallel to that of the untreated plot during the incubation period of the disease and then fell to 4 per 10 sweeps in 15 days. The counts paralleled each other for 6 days, the approximate incubation period of the disease. That the mortality was caused by the virus is indicated by the fact that practically 100 per cent of the larvae in the test plot were infected with the virus (as determined by laboratory examination for polyhedral bodies and by symptoms of the disease) within 4 days after the virus was applied. Unfortunately, examination of the larvae for the presence of virus was not made at the time (September 6) the experiment was begun. However, since larvae in the control plot showed no evidence of infection until 8 days later, it is probably safe to assume that the same situation prevailed in the test plot. By the end of the experiment, the incidence of infection in the control plot had risen to 82 per cent because of the occurrence of a natural epizootic. Nevertheless, the figures indicate that a full-fledged epizootic can be initiated artificially approximately 10 days prior to the time when a natural outbreak of the disease would occur.

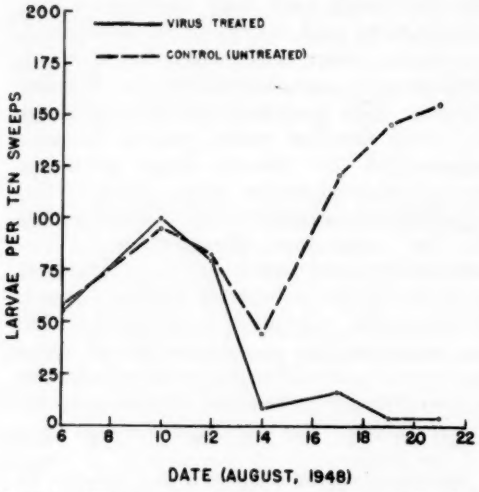

FIG. 1.—The number of larvae per 10 sweeps in the treated and untreated (control) portions of plot 1, during a 15-day period.

The drop in population density between September 10 and 14 may be explained by the parasitization of the caterpillars by *Apanteles medicaginis* Mues. The caterpillar population was mostly in the first three instars; pupation was not a factor. The subsequent rise in the population of the control plot was probably a result of earlier oviposition by *Colias* which was not matched by *Apanteles* oviposition. In the treated plot this secondary rise was apparently prevented by the activity of the virus.

Plot 2.—Test plot 2 and control plot 2 were each 25 by 360 feet in size. The test plot was treated with 1.5 gallons of virus suspension (66,000,000 polyhedra per ml). This experiment was initiated on September 23 and closed on September 30 when the field was cut for hay. On the last day of the experiment no actively moving larvae were found in the test plot. Most of those collected in the sweepings were dead, although a few moribund individuals were found. The

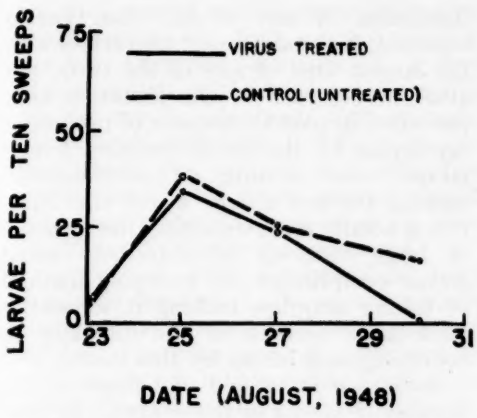

FIG. 2.—The number of larvae per 10 sweeps in the treated and untreated (control) portions of plot 2, during a 7-day period.

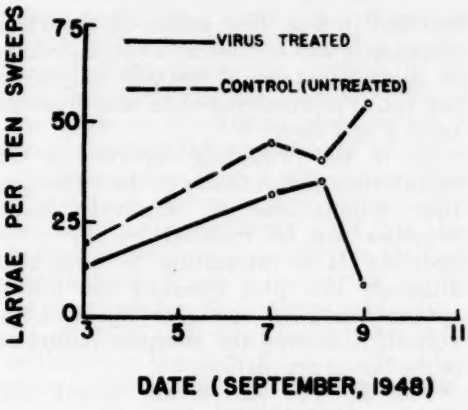

FIG. 3.—The number of larvae per 10 sweeps in the treated and untreated (control) portions of plot 3, during a 6-day period.

average sweeping yielded 4 recently dead larvae (Table 1, Fig. 2). In the control plot, on the other hand, although there was a slight drop in the population (probably due to *Apanteles* parasitization) none of the larvae collected showed any evidence of the disease when examined in the laboratory.

The significance of this test lies in the fact that an epizootic was established in such a small population (never greater than 38 larvae per 10 sweeps). The fact that no active larvae were found in the test plot after 7 days probably does not represent true eradication of the pest in the plot, but it does indicate a very marked reduction in numbers.

Plot 3.—Test plot 3, as well as its accompanying control plot, was 75 by

Table 1.—Number of *Colias* larvae in treated and untreated plots and the percentage of larvae infected with virus.

	Polyhedra Concentration (Per ml.)	Date (1948)	Active Larvae per 10 Sweeps[1]		Per Cent of Larvae Showing Polyhedra	
			Treated	Untreated	Treated	Untreated
1	97,000,000	8– 6	55	58	—	—
		8–10	100	96	100.0	0.0
		8–12	80	84	100.0	0.0
		8–14	10	44	98.0	10.0
		8–17	18	120	100.0	15.0
		8–19	4	145	100.0	75.0
		8–21	4	154	98.0	82.0
2	66,000,000	8–23	6	5	—	—
		8–25	35	38	—	—
		8–27	24	26	—	—
		8–30	0 (4 dead)	16	100.0	0.0
3	57,000,000	9– 3	13	19	—	—
		9– 7	32	45	—	—
		9– 8	35	41	100.0	15.0
		9– 9	8	56	100.0	20.0
4	50,000,000	9– 7	5	4	—	—
		9– 9	40	41	—	—
		9–13	60	72	98.0	2.0
		9–15	36	174	97.0	13.0
		9–17	47	183	98.0	10.0
		9–21	98	353	95.0	28.0

[1] In order to avoid disturbing the larval population of each plot, the count for each day was based on one sample of 10 sweeps, except than in the case of plot 4, which was considerably larger, the counts were based on an average of 3 samples each.

300 feet in size. One gallon of the virus suspension was applied at a concentration of approximately 57,000,000 polyhedra per ml. The resulting data are given in table 1 and figure 3.

As in the preceding experiment, the significance of this test is in the indication that populations of relatively small densities can be reduced by the polyhedrosis. It is interesting to note that although this plot received the lowest concentration of virus for the area involved, it showed the sharpest reduction in the larval population.

Plot 4.—The size of the fourth test plot was 225 by 750 feet. The control plot was of the same dimensions and ran parallel to the test plot but about 100 feet from it. Fifteen gallons of virus suspension (50,000,000 polyhedra per ml.) were applied to the alfalfa of the test plot. This experiment is perhaps the most

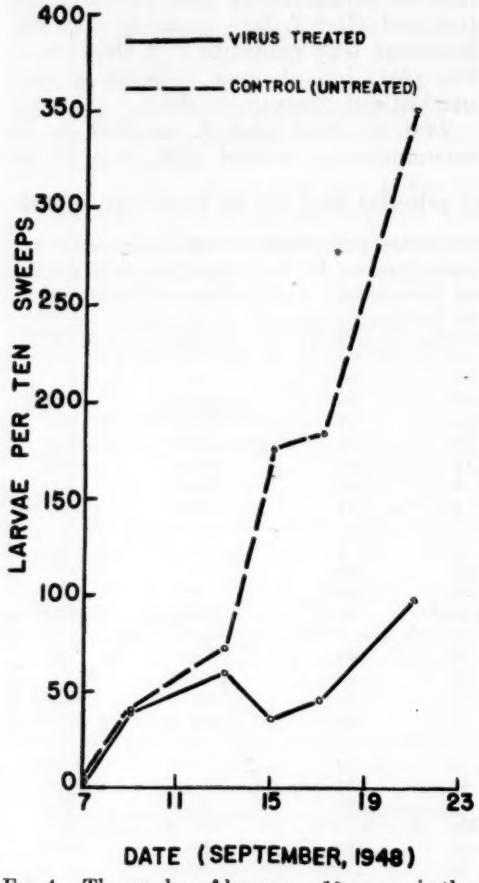

FIG. 4.—The number of larvae per 10 sweeps in the treated and untreated (control) portions of plot 4, during a 14-day period.

significant of any of the four herein reported. Not only was it concerned with the largest area of any of the tests, but also (in contrast to the situation that prevailed in plot 1), because of prolonged egg-laying by the *Colias* females, young larvae were coming on continuously, making the test a very severe one. Also, it is generally recognized that the presence of large numbers of extremely small larvae complicates the sweeping method of taking samples, making it somewhat inadequate because of the difficulty in collecting such larvae by this means.

As shown in table 1 and figure 4, the number of larvae in the control plot rose from 4 per 10 sweeps to 353 per 10 sweeps in 14 days. In treated plots, the population rose to 60 per 10 sweeps by the sixth day, then rose slightly until on the fourteenth day the count was 98 per 10 sweeps. (During the incubation period of the disease the counts approximated each other rather closely.) As indicated above, this slight increase in numbers was undoubtedly caused by the great influx of newly hatched larvae, since at no time did the number of fourth and fifth-instar larvae in the test plot exceed 20 per 10 sweeps. Eventually, these new larvae would also have succumbed to the disease —many of them were already infected by the fourteenth day when the experiment was interrupted by the grower's cutting of the field.

One of the outstanding things indicated by this experiment is that in the fields treated with virus suspension, the caterpillar population was held below an economic level, whereas in the untreated control plot, the population rose to over 350, a level (usually considered as about 100 per 10 sweeps; Smith 1948) at which the insect began to cause marked economic damage as indicated by the amount of observable defoliation of the alfalfa plants.

DISCUSSION.—The data which have just been presented do not in themselves constitute conclusive proof that populations of the alfalfa caterpillar can be regularly controlled by the artificial distribution of the polyhedrosis virus. More extensive tests need to be completed before a safe conclusion can be drawn. Such tests are being contemplated and planned. Furthermore, the new tests should be more detailed and the variables more carefully controlled. Since the field tests here

reported were of a preliminary and exploratory nature only, time was not taken to provide adequate controls of several factors which might have some bearing on the results obtained. For example, there should have been provided a control plot which was sprayed with virus-free water alone, and larval counts should have been made with respect to the sizes and instars of the larvae concerned.

Concurrent with further field tests should be detailed studies on the various ecological factors involved. Accurate and regular determinations of temperature and humidity should be made. During the present preliminary investigation, temperature and humidity recordings were made at the time counts were being made (usually between 10 A.M. and 2 P.M.). On the basis of such readings the temperature in the alfalfa fields, two or three inches above ground, ranged from 79 to 90° F., while the relative humidity ranged from 55 to 95. No readings were made during the night and no hygro-thermograph recordings were made.

Another situation that needs clarification is that relating to the wide distribution of virus in nature and the reasons why the artificial distribution apparently aids in the initiation of an epizootic of the disease. In earlier tests it was found that the soil and surface debris of alfalfa fields naturally contain infectious virus material, indicating that the virus is probably widely distributed in nature. Apparently, however, the new-grown alfalfa leaves do not have on them enough virus, or the virus is not dense enough, to insure contact with early instar larvae. Distributing the virus artificially by spraying increases the concentration of the virus on the alfalfa plant which in turn increases the opportunity of larvae to contact and ingest the virus. Such reasoning is, of course, purely speculative, but it may, in part, explain the fact that epizootics can be induced by the artificial distribution of the virus earlier in the insect generation than occurs naturally.

CONCLUSIONS.—The polyhedrosis (polyhedral virus disease) of the alfalfa caterpillar, *Colias philodice eurytheme* Bdvl., is an important factor in the natural reduction of populations of this insect in California. During the summer of 1948, preliminary field tests were conducted to ascertain the possible practical value of distributing the virus artificially in alfalfa fields threatened by the insect. In general, the results of the preliminary field tests indicate that: (1) The virus, applied as a spray, is capable of causing infection in and markedly reducing populations of the alfalfa caterpillar, at least in small experimental plots. (2) It is possible to initiate an epizootic of the disease in populations of low density (20 to 30 larvae per 10 sweeps), and that even these low populations can be substantially reduced by the artificial dissemination of the virus. (3) It is possible to initiate an epizootic of the disease in a population of caterpillars earlier than it would occur naturally, thus curtailing the amount of damage done to the crop by the insect.

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HARRY L. SMITH JOINS THE BUREAU

Harry L. Smith was recently appointed leader of the new Division of Golden Nematode Control, within the Bureau of Entomology and Plant Quarantine, with headquarters at Hicksville, N. Y. Previously he was leader of the golden nematode project since July 24, 1948.

Some Phases of European Corn Borer Control in Central Maine

JOHN H. HAWKINS and RICHARD THURSTON, *Maine Agricultural Experiment Station, Orono*

Certain local factors set central Maine apart from other areas of the United States where corn is grown. Elevated and wooded regions border the area on the north and west. The surface of the soil is rolling and often rocky except for certain valley or tableland areas. Winter temperatures often reach 0° F. and during 1948 a low of −24° F. was recorded at Winslow. Winter weather, often beginning in November with low temperatures and snowfall, lasts for approximately a 4-month period. The spring months are usually characterized by cool weather and ample rainfall. Summer temperatures are seldom above 90° F. and the nights are cool. The growing season is about 110 days.

WINTER SURVIVAL.—The European corn borer was reported to have been well established in the coastal area of southwestern Maine by the end of 1924 (Caffrey & Worthley 1927). This original infestation was of the multiple generation strain which still persists in the same locality. Several years after the first recorded infestation the European corn borer was found in central Maine. It was apparent from the first that but a single generation of larvae could develop during the short growing season in this area. It is also a fact that the larvae are fully mature by cold weather and do not pupate until after a diapause of considerable length, further indication that the borers are a single-generation strain.

The single-generation strain of the European corn borer now predominates in every community of the State where corn is grown except for certain southern and western coastal areas. General observations and field data indicate that the winter survival of the single generation in central Maine is high. This is borne out by data from field collections of the borers made during the spring season of 1948 when approximately 96 per cent of the larvae collected were alive.

It is probable that the factors involved in the winter survival of the European corn borer are several. However, two of these may be considered as of especial importance. First, the borers become fully mature during the growing season of approximately 110 days and enter hibernation in the diapause stage in which, according to Lozina-Lozinskii (1935), they can resist very low temperatures. The second factor of importance is that of the protection from extremely low temperatures afforded by the blanket of snow which ordinarily covers central Maine to a depth varying from a few inches to 2 feet or more during the 4 months of cold weather. Lozina-Lozinskii (1935), says in part "larvae of *Pyrausta nubilalis* can stand undercooling to about −5.8° F." European corn borers are seldom subject to this temperature because the corn stalks containing the borers are protected at or below soil level by a blanket of snow, which, according to Mail (1930), is am important factor in protecting insects from low temperatures.

EGG SURVIVAL.—Approximately 64 per cent of the eggs of the European corn borers hatched in the experimental plots during 1948. The failure of about 36 per cent of the eggs to hatch can be partially accounted for by the lack of viability of some, by the fact that some of the egg masses became detached and fell off, or were blown off the corn plant by the wind, and because of a small amount of predatism and parasitism. The egg parasite *Trichogramma minutum* Riley and a predaceous mite were present in the plots.

WEATHER AND LARVAL ESTABLISHMENT.—During 1948, approximately 27 per cent of the larvae became established in untreated plots. The weather during the period from July 27 to August 17 was characterized by relatively dry weather with a few dashing showers, light winds and temperatures which dropped as low as 40° F., with an average minimum temperature of 58.8°. These conditions are unfavorable to the establishment of the larvae of the European corn borer on the corn plant (Huber *et al.*, 1928). On the experimental plots where no treatments with insecticides were made, there was a larval mortality of 73.0 per cent before the larvae became established in their host. The heavy mortality of the eggs and early larval instars has not prevented the

European corn borer from increasing in central Maine. According to Baxter (1948) a loss of $660,000 was caused by injuries done to the sweet corn crop by the European corn borer and fall armyworm during the 1948 season.

FARM PRACTICES AND CONTROL.—Cultural practices, now in use in the central Maine area, alone are not sufficient to protect the corn crop from serious damage by the European corn borer. The annual plowing under of corn stalks is required by law to be done before November 1. The plowing is ineffective because the corn stalks are not well covered in most fields. In some cases corn stalks are scattered over the surface of the field and when the plowing is well done many of the stalks are exposed by harrowing during the following spring season.

General observations made in central Maine during the past 10 years indicate that later plantings of corn were least susceptible to corn borer infestations. Experiments conducted in 1946 and 1948 confirm these impressions. Baker & Bradley (1948) state that corn planted the last week in May, or later, ordinarily escapes severe infestation by the one-generation borer, while that planted in late April or early May sustains the worst infestation, and work by Hervey (1932) in western New York shows that plantings made there during the first part of June are much less infested than those made during May. In the central Maine region, however, corn planted in late May and early June is the most heavily attacked (Table 1). If plantings can be delayed until the latter part of June the corn is relatively borer-free. Because of the short growing season, however, plantings normally cannot be delayed in order to escape heavy borer infestations. An early planting of corn in 1946 and observations of early market sweet corn indicate that very early planted corn may also be lightly infested. This is of little assistance to most growers as weather and soil conditions do not permit plantings on most farm lands before the first of June. The timing of planting to avoid heavy corn borer infestations, therefore, would seem to be of little value in central Maine.

Table 1.—Effect of time of planting on the European corn borer in sweet corn.

DATE OF PLANTING	BORERS IN 150 PLANTS
1946	
May 23	73
June 6	122
June 14	68
June 22	27
June 27	9
1948	
May 31	228
June 7	153
June 18	154
June 26	60
June 26	61

In 1946 it had become evident that measures other than the farm practices being relied on for European corn borer control were necessary if the economical production of corn in central Maine was to be continued. Therefore the experimental work already under way was enlarged to include the investigation of insecticidal control.

INSECTICIDAL CONTROL.—Insecticides were applied to plots of corn arranged in random series including check plots and a minimum of five replicates for each insecticide and check. After the first year the corn in the plots was infested by hand in order to assure an even and relatively heavy infestation.

The results in field plots treated with insecticides were judged on the basis of borers found by dissecting a minimum of 20 corn plants from each plot including the check plots.

Hand-operated machinery and power-driven machinery were used in applying the insecticides. A clearance of 27 inches below the machines was sufficient to prevent excessive breakage of the corn plants.

The insecticides applied to the corn in the experimental plots over a period of three years are as follows:

Materials applied in dust form

Ryania 40%
DDT 5% diluted with talc
DDT 5% diluted with sulfur
DDT 3% diluted with talc
DDT 3% diluted with sulfur
Rotenone 1%
Rotenone .75%+3% DDT diluted with sulfur
Chlordane
Chlorinated camphene
Benzene hexachloride
Dichloro diphenyl dichloroethane
Parathion

Insecticides were evaluated on the basis of toxicity to the European corn borer, effect on the plant, residue which might be harmful to livestock, economy, availability, and the general effect of the insecticide on the operator during application.

THE EFFECTIVENESS OF INSECTICIDES.—The controls of the European corn borer obtained over a period of 3 years from four applications of the insecticides referred to in table 2 ranged from 73.1 to 92.7 per cent. The averge control of 78.8 per cent for all the materials applied in dust form may be considered as the approximate control to be expected from their application in central Maine.

Table 2.—Control of the European corn borer by four applications of insecticides.

YEAR	MATERIAL	PER CENT CONTROL
	Dust	
1946	1% Rotenone	75.6
1947	3% DDT+.75°% Rotenone +Sulfur	76.1
1948	3% DDT+Talc	74.6
1948	3% DDT+Sulfur	79.8
1946	Ryania 40-D	92.7
1947	Ryania 40-D	73.1
1948	Ryania 40-D	78.4
1946	5% DDT+Talc	82.9
1947	5% DDT+Talc	75.9
1948	5% DDT+Talc	78.8
	Spray	
1948	DDT	86.0
1948	Ryania	81.4

The average percentage of control obtained by the insecticidal dusts applied in 1948 was 77.8 while the average of the two sprays obtained was 83.7, a difference of 5.9 per cent in favor of the insecticides applied as sprays.

Dusts containing chlorinated camphene and benzene hexachloride used in experiments for the control of the European corn borer were somewhat less effective than Ryania and DDT dusts applied in the same manner and in comparable amounts.

Treating of corn with a dust containing 5 per cent dichloro-diphenyl-dichloroethane resulted in 93.5 per cent control and the use of a dust containing 2 per cent parathion was 87.8 per cent effective. Control obtained by either of these dusts did not quite equal that of 96.3 per cent obtained from the application of a dust containing 5 per cent DDT and sulfur. Hand-operated dusters were used in this experiment. Although the amounts of insecticides used were excessive the results obtained were satisfactory from the standpoint of control and their use would be economically justified in regions where high prices for sweet corn prevail.

It is apparent that results obtained from the use of insecticides for the control of the European corn borer in central Maine are somewhat lower than they are in other areas. Therefore efforts have been made to combine insecticides and otherwise to step up the effectiveness of the materials. Attempts to increase the effectiveness of insecticides in European corn borer control by the combining of different materials have not proven entirely successful. There is, however, an indication that when sulfur is used as a diluent for DDT an increase in control is obtained. This increase cannot be accounted for by any data obtained. Possible reasons for increased effectiveness by the addition of sulfur are suggested as being due to activation of the DDT, activation of the insect, and to additional insecticidal action of the sulfur itself.

INSECTICIDAL RESIDUES.—Two materials showed promise: Ryania because it is said to be relatively safe for use on corn where any portion of the corn plant is to be fed to livestock, and DDT where residues are not a problem. Corn plants taken from the field plots which had been treated with DDT showed slight residue when analyzed, except for 1948, when no trace of DDT was found in samples from the plots receiving not more than 240 pounds per acre for four treatments.

INFLUENCE OF RAINFALL ON RYANIA DUST.—It is a well known fact that rainfall occurring after the application of an insecticide influences control. Preliminary investigations during 1946 indicated that rainfall might be of especial importance as a factor limiting the effectiveness of insecticides in European corn borer control. Data obtained during 1947 show that no control was obtained when a single early treatment of 40 per cent Ryania dust was applied on July 21. This application was followed by 1.2 inches of rain during the 6-day period after treat-

ment. Other plots received this first application plus a second application of Ryania dust on July 27. After the second dust was applied 0.9 of an inch of rain fell within the next 6 days, and 25.8 per cent control was obtained. A third dust, in addition to the second application, was applied on August 3, following which 0.2 of an inch of rain fell. In these plots 68.8 per cent control was obtained. An additional dust, the fourth application, applied on August 9 was followed by 1.25 inches of rain within 6 days after application. The control obtained was an increase of but 4.3 per cent over that where three dusts were applied.

There is no doubt that factors other than rain entered into the results obtained from the application of insecticides during 1947. However, if we may judge on the basis of the data, it is evident that rainfall affected the first and fourth dusts applied in the experimental plots. Rainfall sometimes causes a delay in the application of insecticides because muddy conditions make it impossible to enter corn fields and apply insecticides on schedule. It is entirely possible that continued rain, such as sometimes occurs in central Maine, might seriously handicap the efforts to control the European corn borer. It is also possible that high winds might continue long enough to affect seriously the timing of the insecticide application. Therefore, adjustment in the timing of insecticidal treatments may be necessary to compensate for weather which is unfavorable to the application and performance of the insecticide.

TIMING OF INSECTICIDAL APPLICATIONS.—Preliminary experiments with insecticides used in European corn borer control indicated that insecticidal dusts applied on certain dates were more effective than when the dusts were applied on other dates. Data obtained during 1948 showed that single applications of 40 per cent Ryania dust applied in July 31 and on August 6 resulted in approximately 40 per cent control as compared to 78.8 per cent control when four applications of the same material were made.

Pepper & Haeussler (1944) say that insecticides are effective during a 5-day period following application. Therefore the single application of 40 per cent Ryania dust made on July 31 should be effective during the period between July

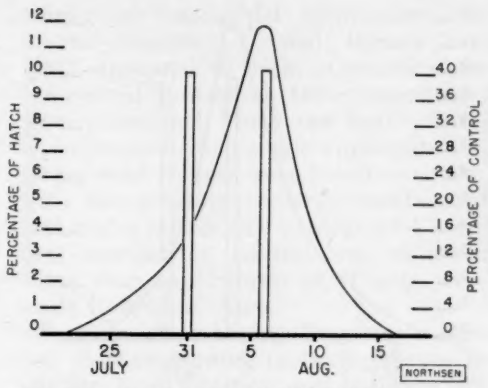

FIG. 1.—Percentage control of the European corn borer obtained by 3 and 4 applications of 40 per cent Ryania dust. Bar on the left represents percentage of control obtained by 3 applications. Bar on the right represents the percentage of control obtained by four applications. Previous applications were made on July 26 and on July 31.

31 and August 5. This period corresponds to the time of rapid rise in the percentage of eggs hatching, and consequently to the presence of considerable numbers of the first instar larvae of the European corn borer (Fig. 1). The second single application of Ryania dust was made on August 6. It would be most effective during the peak of egg hatch and for 5 days afterwards, covering a time when maximum numbers of first instar-larvae would be present.

Turner (1945) says in effect that it may be taken as a working hypothesis that only the first instar larvae of the European corn borers are killed by insecticides.

It is evident that the relatively high percentage of control obtained by the two single treatments with Ryania dust was due in a large degree to the fact that they were applied so as to be most effective at the peak of egg hatching and at the time when maximum numbers of first instar larvae of the European corn borer were present.

THREE VERSUS FOUR APPLICATIONS.—An average increase for three years of 4.3 per cent control of the European corn borer was obtained by the addition of a fourth application of 40 per cent Ryania dust.

Data obtained during 1948 were plotted on a seasonal hatching curve and the relation of the curve to the effect of three and four applications of Ryania dust is shown in figure 2. This figure shows that

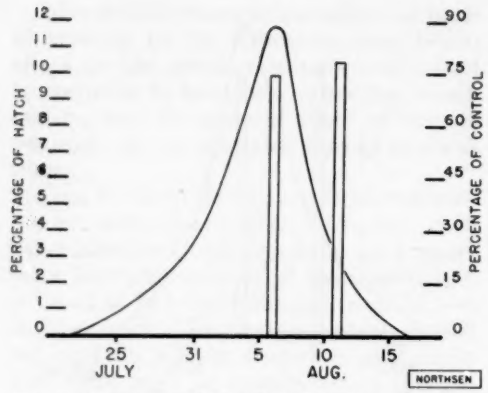

FIG. 2.—Percentage of control of the European corn borer obtained by single applications of 40 per cent Ryania dust as related to percentage of eggs hatching.

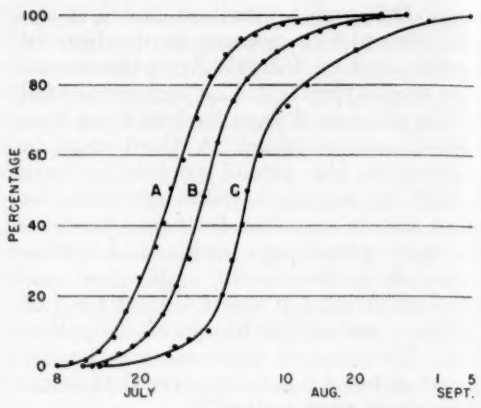

FIG. 3.—The cumulative percentage frequency curves. A, represents moth emergence; B, represents oviposition; and C, represents hatching of the eggs of the European corn borer.

the three applications of Ryania dust were most effective over the period of time when the maximum number of borers were hatching. On the other hand, only a small percentage of eggs remained unhatched and consequently only a small percentage of susceptible first instar larvae were present on the date when the fourth application was made. The lateness of application is an important reason why the addition of a fourth treatment resulted in the small percentage increase in the control of the European corn borer.

MOTH EMERGENCE, OVIPOSITION, AND HATCHING.—Finding of corn borer eggs in the field and the development of the corn plants have been the two widely used criteria for determining the timing of application of insecticides (Pepper & Haenseler, 1944). The date of emergence has been used effectively in timing insecticidal applications for the control of the apple maggot (Lathrop & Hilborn, 1948). It appears that the time of emergence of the adults might serve as a practical basis for timing the applications of insecticides for European corn borer control.

The cumulative percentage frequency curves representing moth emergence, A; oviposition, B; and hatching, C; are of a similar pattern (Fig. 3). This similarity indicates that the rise in populatign of moths resulting from emergence is followed by increase in oviposition and hatching. The cumulative curves indicate that there is some variation in the time interval elapsing between the events of moth emergence, oviposition, and hatching of the European corn borer eggs.

A study of these data at different percentage levels (Table 3) shows that this variation ranges from 4 to 7.7 days for the interval between moth emergence and oviposition and from 11 to 17.8 days between moth emergence and hatching. It is apparent from a study of the data that the shortest period elapsing between events is at the time when the percentage of the moth emergence is rising rapidly. The time elapsing between the moth emergence, oviposition, and hatching is of interest because these events are factors which are useful in timing applications of insecticides.

The initial emergence of the moths of the European corn borer has been used in central Maine to warn corn growers in advance of when the eggs are likely to be found. The rise in moth emergence at the

Table 3.—Days elapsing between emergence of the European corn borer moths and oviposition and hatching.

PER CENT OCCURRENCE LEVEL	DATE FOR MOTH EMERGENCE	DAYS TO OVIPOSITION	DAYS TO HATCHING
1	July 11	6	14
10	July 16	5.4	13.5
20	July 19	5.7	12.8
30	July 21	5.7	12.2
40	July 22	5.5	11.9
50	July 24	5.0	11.5
60	July 25	4.7	11.3
70	July 27	4.5	12.5
80	July 29	4.9	15.2
90	Aug. 1	7.7	17.8
100	Aug. 23	5	13

height of the season is suggested as a basis for warning that there will be corresponding rises in oviposition and hatching following within approximately 5 or 6 days and 11 or 12 days, respectively.

SUMMARY.—About 96 per cent of the single-generation strain of the European corn borer survived the winter in central Maine during 1948. Snow coverage protects against existing low temperatures.

Summer mortality of eggs and larvae are approximately 36 and 73 per cent, respectively.

Farm practices alone are not effective control measures.

Adjustments to accommodate for rainfall and wind are necessary for the proper timing of insecticidal applications. Of several insecticides tried Ryania and DDT appeared to be most practical for the central Maine area. Other insecticides were promising. Forty per cent control was obtained when single applications of 40 per cent Ryania were timed to concur with the presence of large numbers of first instar larvae. An average of 4.3 per cent increase in control was obtained when four applications of Ryania were made instead of three.

Cumulative percentage frequency curves and data concerning moth emergence in relation to oviposition and hatching are useful in predicting when insecticides can be applied in order to be most effective.

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New Advances in Alfalfa Snout Beetle Control

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Studies of the alfalfa snout beetle, *Brachyrhinus ligustici* L. during the spring of 1947 at Minetto, N. Y. were limited to cage and field tests comparing the effectiveness of DDT, benzene hexachloride and chlordan as dusts with the standard peanut shell-sodium fluosilicate bait (Table 1) now used in the annual New York State control program. The tests for 1948, however, were somewhat more extensive, using not only small hand treated plots and several new materials, but also large field tests and employing both fixed and rotary-wing aircraft.

In field tests in 1947, 5 per cent DDT, 5 per cent benzene hexachloride said to contain 0.3 per cent gamma isomer, and 5 per cent chlordan mixed with pyrophyllite were compared with peanut shell bait. The dusts were applied at the rate of 50 pounds per acre with a power duster having 8 nozzles set 18 inches apart and the

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Table 1.—Results from 1947 field tests comparing the effectiveness of peanut shell bait with DDT, benzene hexachloride and chlordan dusts for the control of the alfalfa snout beetle.

TREATMENT	DUST PER CENT CONC.	NO. BEETLES		PER CENT REDUCTION
		Dead	Alive	
Jefferson County, N. Y.				
DDT	5	471	182	72
Chlordan	5	615	35	95
Benzene Hexachloride	0.3γ	536	112	83
Peanut Shell Bait—Sodium fluosilicate[1]		465	187	71
Oswego County, N. Y.				
Benzene Hexachloride	0.3γ	872	28	96

[1] Formula: Peanut shells 85 lbs., sugar 20 lbs., soy bean flour 18 lbs., sodium fluosilicate 8 lbs., formalin 1 pt. and water, 12 gals. to make up 3 bu. of bait.

same distance from the ground. Experiments with plots approximately one-half acre in size and replicated twice were located in Oswego County and in Jefferson County.

Statistical analysis of the data for Jefferson County showed no significant differences between treatments. This was in large part due to great differences in snout beetle infestation and alfalfa stands in the different plots. These data are recorded in table 1. If, however, chlordan is given an arbitrary rating of 100, the materials may be scored as follows: benzene hexachloride—88, DDT—77 and peanut shell-sodium fluosilicate bait 76.

In cage tests in 1947, the same materials tested in the field were used as follows. A large area was scraped bare of all vegetation and 18 blocks of sod approximately 1 square-foot in area were dug from mixed plantings of red clover and alfalfa and transplanted in the cleared area late in April. Screen cages were placed over each block of sod. All applications of insecticides were made on May 11. The dusts were applied with a small garden "puff" duster at a rate approximating that applied in field tests. The standard peanut shell bait was applied much more heavily than in field applications. Each treatment was replicated three times in randomized blocks. Fifty beetles collected from untreated fields were introduced into each cage May 11 and May 13. On May 16, 100 beetles were added to each cage. There were two sets of checks, one in which beetles were introduced and one in which no beetles were introduced. Counts were made on May 24. These results are given in table 2. All the treatments were significantly better than the untreated checks. Although chlordan was by far the most effective, none of the treatments were significantly different when measured on the basis of reduction in population of the living beetles. When measured on the basis of reinfestation of the treated areas, however, both benzene hexachloride and chlordan were significantly better than all the other materials at the 1 per cent level. (Table 3.) DDT was somewhat erratic in its action.

Since, in cage tests in 1946, sublethal doses of DDT and benzene hexachloride appeared to affect oviposition by the alfalfa snout beetles, a further check was made on all the living beetles recovered from the cage tests described above. These beetles were dissected and examined for the presence of eggs in the ovarioles. These results are presented in table 4. The most interesting feature of this examination was the fact that peanut-shell bait gave slightly better kills than benzene hexachloride under the conditions of this experiment but 98 per cent of the living beetles in the peanut-shell bait developed eggs while only 33 per cent of those in the

Table 2.—Cage tests comparing the effectiveness of peanut shell bait with several chlorinated hydrocarbons for the control of the alfalfa snout beetle. May 24, 1947, Oswego County, N. Y.

Treatment	Dust Per Cent Conc.	No. Beetles		Per Cent Reduction
		Dead	Alive	
DDT	5	520	11	98
Chlordan	5	523	0	100
Benzene hexachloride	0.3γ	395	90	82
Peanut Shell Bait—Sodium fluosilicate		434	98	83
Check—Untreated		56	463	11

Least Significant Difference at 5% = 23.5
Least Significant Difference at 1% = 34.2

Table 3.—Cage tests comparing the efficiency of peanut shell bait and three chlorinated hydrocarbon dusts in preventing development of a new generation of alfalfa snout beetle. October 8, 1947, Oswego County, N. Y.

Treatment	Per Cent Dust Conc.	No. Plants		No. Larvae Found	Ave. Per Cent Non-Inf. Plants
		Inf.	Non-inf.		
DDT	5	9	28	37	51.3
Chlordan	5	1	56	0	98.6
Benzene hexachloride	0.3γ	5	63	5	93.0
Peanut shell bait		32	15	29	29.0
Check—No Beetles	—	0	64	0	—
Check—With Beetles	—	23	6	7	19.0

Least Significant Difference at 5% = 35.0
Least Significant Difference at 1% = 50.3

Table 4.—Effect of peanut shell bait, DDT, benzene hexahcloride and chlordan dusts on oviposition by the alfalfa snout beetle. May 24, 1947, Oswego County, N. Y.

Treatment	Dust Conc.	Living Beetles	Beetles in Which Eggs Had Developed	Living Beetles in Which Eggs Developed
DDT	5%	11	4	36%
Chlordan[1]	5	0	0	0
Benzene hexachloride	0.3γ	100	33	33
Peanut shell bait—Sodium fluosilicate	—	98	89	98
Check	—	473	444	93

Least Significant Difference at 5% = 24.6
Least Significant Difference at 1% = 37.3
[1] Not considered in the statistical analysis.

benzene hexachloride treatment developed eggs. Further examinations in the field of DDT, benzene hexachloride and chlordan plots at a later date confirmed the fact that sublethal doses of these materials suppressed the formation of eggs in the alfalfa snout beetle. DDT was less effective than chlordan and benzene hexachloride in that order in this respect in most cases.

A further check was made on October 8 on the cage test plots for the number of red clover and alfalfa plants surviving. The plants were scored as infested or non-infested, depending upon whether or not the roots showed signs of having been attacked by larvae developing in the caged area. These results are given in table 3. These results were not wholly as might be expected when compared with the number of beetles in which eggs had developed. Intense competition between large numbers of larvae, faulty caging of a DDT plot, and larvicidal action of benzene hexachloride and chlordan not found in DDT are suggested as possible explanations for some of the discrepancy. Chlordan and benzene hexachloride in this test, as in all others during 1947, proved to be the most promising new materials for controling the alfalfa snout beetle.

In 1948, several tests using chlorinated hydrocarbons and phosphates in small plot field experiments and air application were initiated in Jefferson County.

In the hand dusted plots nine different dust materials, some at several levels of concentration, were compared with the standard peanut shell bait in order to determine the most effective level of concentration and formulation for the control of the alfalfa snout beetle. DDT was used at two levels of concentration, both as a regular mixed dust and an impregnated dust. Chlordan and benzene hexachloride were also impregnated on pyrophyllite while the two piperonyl cyclonenes were proprietary formulations said to contain 0.5 per cent piperonyl cyclonene and both 0.25 per cent rotenone and 0.05 per cent pyrethrins in one dust mixed with pyrophyllite and merely rotenone and piperonyl cyclonene in the second mixture. Proprietary mixtures of 5 per cent DDD, 1 per cent parathion and 10 per cent chlorinated camphene regular mixed dusts were also used.

The plots, which were 10 by 20 feet in size and replicated three times in randomized blocks on a freshly plowed alfalfa field, were treated once with a rotary hand duster using approximately 50 pounds of dust per acre. The peanut shell bait was applied at the rate of about 3 bushels per acre. Insect counts were made periodically at intervals for about a week. These results are recorded in table 5.

Benzene hexachloride and parathion were the most promising materials tested while chlordan was not effective at the low concentration at which it was used. DDT, which appeared to be more effective as an impregnated dust, dichlorodiphenyl dichloroethane and the two proprietary piperonyl cyclonene dusts were not as effective as the standard peanut shell bait. Chlorinated camphene, while slow in its action, showed some promise at the concentration used. The standard peanut shell-sodium fluosilicate bait gave good commercial control on the freshly plowed infested alfalfa field.

The five most promising dust formu-

Table 5.—A comparison of several organic insecticides when applied as dusts in small hand plots. April 28, 1948, Jefferson County, N. Y.

Treatment	Dust Per Cent Conc.	Per Cent Reduction 24 hrs.	72 hrs.	144 hrs.
DDT	1[1]	23	24	42
Chlordan	1[1]	21	18	58
Benzene hexachloride	1γ[1]	75	79	85
Piperonyl cyclonene Pyrethrins Rotenone	0.5 0.05 0.25	14	21	25
Piperonyl cyclonene Rotenone	0.5 0.125	54	22	30
DDT	5	15	40	27
DDD	5	35	14	35
Parathion	1	75	71	91
Chlorinated camphene	10	22	27	76
Peanut Shell Bait— Sodium fluosilicate		14	43	82

[1] Impregnated.

Table 6.—A comparison of several synthetic organic insecticides when applied as dusts by helicopter for the control of the alfalfa snout beetle. April 29, 1948, Jefferson County, N. Y.

Treatments	Dust Per Cent Concentration	Per Cent Reductions 48 hrs.	144 hrs.	292 hrs.
Parathion	1	25	62	100
DDT	5	11	14	83
Chlordan	5	12	48	100
Benzene hexachloride (impregnated)	1γ	22	36	100
Chlorinated camphene	10	19	55	100

lations were selected from the hand plots described in the experiment above and each was applied to a single three acre block of freshly plowed infested alfalfa ground at the rate of about 50 lbs. per acre by a helicopter. Insect counts were made peridoically at four different stations in each block for a week. The results are summarized in table 6. Although good results were obtained with all the materials, a reinfestation occurred about 5 days after the last count indicating that at least two applications of insecticide are needed, one just before the peak and one at the peak of beetle emergence.

In another trial, three adjacent alfalfa fields were treated by use of a biplane using 5 per cent DDT, 5 per cent chlordan and 3 per cent gamma isomer mixed with pyrophyllite at the rate of about 50 pounds per acre. Each field was about 5 acres in area. Insect counts were made at four stations in each field periodically for a week. In the fall, as a further check, diggings were made of 25 roots in each treatment and also in adjacent peanut-shell bait treated fields in order to determine the percentage of new infestations in these areas. These results are recorded in table 7. No attempt was made to compare fixed-wing aircraft dusting with rotary-winged aircraft treatments, since the applications of materials were made on two different types of infestation—one a plowed field and one a grassy plot. As in 1947, chlordan appeared to be the most effective material used. Benzene hexachloride in this experiment was very disappointing and gave much poorer results than when used in other experiments at one-third the gamma content. The reason for this is unknown. DDT while giving very poor kills in this test showed only one-half as much reinfestation as the peanut shell bait.

Table 7.—A comparison of three chlorinated hydrocarbons when applied as dusts by airplane for the control of the alfalfa snout beetle. May 4, 1948, Jefferson County, N. Y.

Treatment	Per Cent Dust Conc.	Per Cent Reduction			Per Cent New Infestation Fall Diggings
		72 hrs.	192 hrs.	264 hrs.	
DDT	5	0	0	14	20
Chlordan	5	40	80	90	10
Benzene hexachloride	3γ	9	10	0	60
Peanut Shell Bait	—	—	—	—	40

SUMMARY AND CONCLUSIONS.—In several field trials during the last two years conducted in Oswego and Jefferson Counties, parathion, chlordan, benzene hexachloride and chlorinated camphene appeared very promising for alfalfa snout beetle control. These materials were all superior to the standard peanut shell bait. DDT and dichlorodiphenyl dichloroethane were less effective regardless of whether applied by ground or air machinery and were somewhat erratic in their results. Piperonyl cyclonene was not effective.

One of the outstanding attributes of some of these new materials, especially the chlorinated hydrocarbons, was the sublethal effects which apparently inhibited the formation of eggs in the ovarioles. The significance of this discovery is obvious. Resistant specimens which were not killed by the treatments may be unable to reproduce individuals for subsequent reinfestations. The minimum effective dosage would be therefore somewhat less than required for 95 per cent control.

Air application by fixed or rotary winged aircraft was very promising for the control of the snout beetle although subsequent reinfestations indicated that at least two applications were needed for the most effective control.

DR. A. D. IMMS DIES

Dr. Augustus Daniel Imms died April 3, 1949, at the age of sixty-eight, at Sidmouth, England. Dr. Imms was educated at the University of Birmingham and at Christ College, Cambridge. At the University of Birmingham he was exhibition research scholar, assistant demonstrator in zoology and professor of biology. Later he was forest zoologist to the government of India, reader in agricultural entomology at Manchester University and chief entomologist at the Rothamsted Experiment Station.

Control of the Clover Root Borer

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From 1946 until 1948, experiments have been conducted to determine the comparative efficiency of benzene hexachloride, chlordan, parathion and DDT in the control of the clover root borer, *Hylastinus obscurus* Marsham.

After 9 years of intensive study of red clover root diggings, it was found that in the first crop or first cutting year about 40 per cent of the red clover roots were infested with clover root borer with an average of 1.5 borers per plant. In the second crop year, the infestation was nearly 100 per cent with an average of 3.8 borers per plant. All of the clover root borer control experiments described here were on first crop year red clover.

Methods and Materials.—Both dust and sprays were applied in several tests for 3 years. The dusts were applied by a rotary hand duster and the sprays by a knapsack sprayer. In 1946 and 1947, the commercial dusts were diluted with pyrophyllite while in 1948 the dusts were made by impregnating pyrophyllite with the toxicants.

Since the adult beetle is above ground for a short time in the spring during migration, this period was selected as the most vulnerable place in the life cycle. Tanglefoot traps were set up around first crop year red clover fields to determine the peak migration period. The first application was applied roughly one week previous to the assumed peak flight based on flight history, the second at the peak flight and the third 1 week later. Where only one application was used, it was applied at the peak of the migration.

In 1946, only two materials were used. DDT dust and benzene hexachloride which was applied both as a spray and as a dust, were tried on two experiments. In the tests for 1947, chlordan dust was added and a mixture of DDT and benzene hexachloride as a dust was also used. While in 1948, parathion dust was added to the other three materials tested the previous two years.

The test plots were randomized and unless otherwise stated were 20 by 20 feet and replicated three times with one exception when four replicates were made.

Table 1.—Exp. 1. Summary of control data for *Hylastinus obscurus* Marsham with DDT and benzenehexachloride applied May 15, 23 and 30 at Minetto, N. Y., 1946.

Material	Toxicant per Acre in Pounds	Number Infested Plants	Treatment Means
Benzene hexachloride spray .13% gamma	0.60γ	0	0.00
Benzene hexachloride dust .66% gamma	0.33γ	1	0.25
DDT dust 5%	2.50	13	3.25
Check		51	12.25
Least significant difference at the 5% level			3.12
Least significant difference at the 1% level			4.48

Residue samples were taken during 1948 in random areas in each plot just before the crop was cut for hay and residue determinations were made within 48 hours for total chloride using total chloride electrometric titration for benzene hexachloride, chlordan and DDT while the Averell and Norris Colorometric Method was used for the determination of parathion.

A predetermined number of clover roots were dug from each plot in the fall and each root was dissected and examined under a lower power binocular microscope to determine the infestations of the clover root borer.

Results of Tests in 1946.—In experiment 1 (Table 1) 60 plants per treatment were examined and the results, in the

[1] Now Assistant Entomologist at Louisiana State University who was in charge of the work during 1946 and 1947 while at Cornell University.

[2] The authors wish to acknowledge the excellent assistance of Mr. S. S. Ristich during the 1947 season.

Table 2.—Exp. 2. Summary of control data for *Hylastinus obscurus* Marsham with DDT and benzenehexachloride applied May 10, 15, 30 at Minetto, N. Y., 1946.

Material	Toxicant per Acre in Pounds	Number Infested Plants	Treatment Means
Benzene hexachloride spray .13% gamma	0.60γ	1	0.33
Benzene hexachloride dust .33% gamma plus equal amount	0.16γ +		
DDT dust 2.5%	0.63	7	2.33
Benzene hexachloride dust .66% gamma	0.33γ	8	2.67
DDT dust 5%	2.50	18	6.00
Check		61	20.33
Least significant difference at the 5% level			6.76
Least significant difference at the 1% level			9.88

order of their effectiveness, are indicated by the treatment means. None of the materials used caused any phytotoxicity. As may be seen in table 1, all treatments were significantly better than the check at the 1 per cent level while benzene hexachloride, as a spray and as a dust, was significantly better than DDT at the 5 per cent level.

In experiment 2 (Table 2) the results of the treatments are recorded in order of their effectiveness. Eighty plants were examined per treatment. All treatments were again highly significantly better than the checks; however, benzene hexachloride as a spray, dust or combined with an equal amount of DDT, was not significantly better than DDT alone under the conditions of this experiment.

Although the experiments described above were set up specifically for clover root borer control, it was thought that such tests would offer an opportunity to study the effect of these materials upon some of the important pests of red clover. Accordingly, population counts were made weekly by net sweepings of the clover bud weevil, *Hypera nigrirostris;* the clover head weevil, *Hypera meles;* the clover seed weevil, *Tychius griseus;* the tarnished plant bug, *Lygus oblineatus;* the clover root curculio, *Sitona hispidula;* the meadow spittle bug, *Philaenus leucophthalmus;* the potato leaf hopper, *Empoasca fabae;* and several species of aphids.

Both materials gave an excellent initial control of the aphid species present at all the formulations and concentrations used but within 2 weeks of the last dusting date the population of many treated plots exceeded that of the checks. In the case of the meadow spittle bug both materials gave good control at the 5 per cent concentration of toxicant. Smaller concentrations of toxicant were not effective. Benzene hexachloride was superior to DDT for meadow spittle bug control.

Concentrations of 5 per cent toxicant were needed with both DDT and benzene hexachloride to be effective for clover head weevil and clover bud weevil control.

Both materials gave effective control of the tarnished plant bug, clover root curculio and the potato leafhopper. Benzene hexachloride gave better control of tarnished plant bug and aphids whereas DDT showed to somewhat better advantage against the clover root curculio and the potato leafhopper.

RESULTS OF TESTS IN 1947.[1]—Tables 3 and 4 list the results of the treatments in the order of their effectiveness. In both experiments 80 plants were examined in each treatment. In experiment 3 (Table 3) all treatments were significantly better than the check at the 1 per cent level, however there were no significant differences between treatments. All materials gave excellent control of the clover root borer. In experiment 4, again all treatments showed a high degree of clover root borer control with all the materials tested with benzene hexachloride being somewhat better than benzene hexachloride-DDT dust and chlordan dust. None of the materials or combination of the materials caused any phytotoxicity. In all of the treated plots there was a striking increase in the number of blooms and in the fullness of the heads of the clover plants. There was also a marked decrease in the amount of leaf spot diseases.

RESULTS OF TESTS IN 1948.*—In a study of the results of 1947 with regard to the number of applications it was noted

* The authors wish to acknowledge the excellent assistance of Mr. Arthir Mucka during the 1948 season.

Table 3.—Exp. 3. Summary of control data for *Hylastinus obscurus* Marsham with DDT, benzenehexachloride, and chlordan applied May 19, 27 at South Hannibal, N. Y., 1947.

MATERIAL	TOXICANT PER ACRE IN POUNDS	NUMBER INFESTED PLANTS	TREATMENT MEANS
Benzene hexachloride dust .63% gamma	0.31γ	0	0.00
Chlordan dust 5%	2.5	0	0.00
DDT dust 5%	2.5	6	2.00
Check		43	14.33
Least significant difference at 5% level			4.57
Least significant difference at 1% level			6.93

Table 4.—Exp. 4. Summary of control data for *Hylastinus obscurus* Marsham with DDT, benzenehexachloride and chlordan applied on May 27 at South Hannibal, N. Y., 1947.

MATERIAL	TOXICANT PER ACRE (POUNDS)	INFESTED PLANTS	TREATMENT MEANS
Benzene hexachloride dust .63% gamma	0.31γ	2	0.66
Chlordan dust 5%	2.5	13	4.33
Benzene hexachloride dust .63% gamma plus equal amount	0.16γ +		
DDT dust 5%	1.25	17	5.66
Check		54	18.00
Least significant difference at 5% level			4.42
Least significant difference at 1% level			6.69

Table 5.—Exp. 5. Summary of control data for *Hylastinus obscurus* Marsham with DDT, chlordan, benzenehexachloride, and parathion applied May 27 at Fulton, N. Y., 1948.

Material	Toxicant Per Acre in Pounds	Residue ppm on Clover	Number Infested Plants	Treatment Means
Benzene hexachloride dust 1% impregnated	2.25γ	1.3	0	0.00
Parathion dust 1% Impregnated	2.25	0.0	1	0.33
Chlordan dust 1% Impregnated	2.25	0.5	2	0.67
DDT dust 1% Impregnated	2.25	0.4	5	1.67
Check			8	2.67
Least significant difference at 5% level				1.35
Least significant difference at 1% level				1.97

that there were no significant differences in the control of the root borer between two applications and one application, hence it was decided to apply but one application at the peak of migration in 1948.

During 1948 the number of plants examined was reduced to 30 per treatment. In experiment 5 (Table 5) chlordan, parathion and benzene hexachloride were highly effective in controlling the clover root borer with but a single well timed application. DDT was less effective in this experiment at this dilution, even though the dosage was nearly as great as in the experiments of the previous two years.

In experiment 6 (Table 6) benzene hexachloride again was highly superior to the check at the 1 per cent level and somewhat better than DDT. Parathion, while being similarly significantly better than check at 1 per cent level, was not really different from DDT for the control of the clover root borer. DDT and chlordan

Table 6.—Exp. 6. Summary of control data for *Hylastinus obscurus* Marsham with DDT, chlordan, benzenehexachloride, and parathion applied May 26 at Minetto, N. Y., 1948.

Material	Toxicant Per Acre in Pounds	Residue ppm on Clover	Number Infested Plants	Treatment Means
Benzene hexachloride dust 1% Impregnated	1.50γ	0.9	0	0.00
Parathion dust 1% Impregnated	1.50	0.0	1	0.33
Chlordan dust 1% Impregnated	1.50	0.1	4	1.33
DDT dust 1% Impregnated	1.50	0.2	7	2.33
Check			1	3.33
Least significant difference at 5% level				2.12
Least significant difference at 1% level				3.08

Table 7.—Exp. 7. Summary of control data for *Hylastinus obscurus* Marsham with DDT, chlordan, benzenehexachloride and parathion applied June 1 at Fulton, N. Y., 1948.

Material	Toxicant Per Acre in Pounds	Residue ppm on Clover	Number Infested Plants	Treatment Means
Benzene hexachloride spray 50% wettable	1.00γ	0.0	5	1.67
Chlordan spray 50% wettable	1.00	0.0	6	2.00
Parathion spray 25% wettable	1.00	0.0	7	2.33
DDT spray 50% wettable	1.00	2.3	14	4.67
Check			11	3.67

Differences in treatment means were not significant.

were not as effective in this experiment as in some of the others previously.

In the spray experiment (Table 7) there were no significant differences between the treatments and check. This may be in part attributed to the lower rate of application and possibly inferior coverage and penetration of the crowns of the clover plants.

Since residues from the use of insecticides potentially hazardous to livestock, honeybees and pollinating insects are among the most important limiting factors in the use of insecticides on forage crops, only the minimum amount of insecticides needed for commercial control should be used. Results from experiments conducted in 1946 and 1947 indicated that there was no significant differences in control between one, two and three applications of an insecticide if these applications were properly timed. In 1948 a single application of several different insecticides made at peak migration flight of the adults of the clover root borer not only gave effective controls but also almost negligible amounts of residue at hay cutting time. These results may be seen in table 7. Fortunately in New York, migration occurs in late April and early May when the clover plants are merely a few inches high and dust applied to these plants sifts down into the crowns where it is not only most effective but also below the height of the cutter bar at harvest time. The new growth which makes up most of the hay at harvest time is thus largely free of insecticides.

SUMMARY.—Three years of field experiments have shown that benzene hexachloride, as a dust, consistently gave a greater reduction of clover root borer in the first crop year red clover than other

materials tested. Benzene hexachloride at the amounts used did not reduce the palatability of the hay to livestock. Parathion and chlordan, in that order, gave high degrees of control, however they were not as consistent in their results as benzene hexachloride. All materials when used as sprays at the rate of one pound of actual toxicant per acre were not satisfactory. Benzene hexachloride as a dust at the rate of 2.25 pounds actual gamma isomer per acre gave a small amount of injury, however 1.5 pounds actual gamma isomer per acre did not give any phytotoxicity and the effectiveness of the toxicant was not reduced.

Residue deposits may be reduced by making a single application of insecticide at the peak flight period of the clover root borer instead of two or three lighter applications at pre-flight periods with approximately the same degree of control. A single well-timed application of insecticides gave negligible residues, and greatly reduced the potential hazard to livestock, honeybees and other pollinating insects.

Biology and Control of the Sweet Clover Weevil

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The sweet clover weevil, *Sitona cylindricollis* Fahr., a serious pest of European origin, was first recorded from the North American continent near Montreal, Canada, in 1924 by Brown (1940). It has since become wide-spread in sweet clover growing areas across Canada and the northern states from the eastern coast clear through to the Rocky Mountains on the west.

According to a recent letter from Mr. C. F. W. Muesebeck the U. S. National Museum contains specimens from Ontario Canada, and Vermont, Connecticut, Maryland, Indiana, Ohio, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Montana. Additional localities listed by Brown are Massachusetts New York, New Brunswick, Nova Scotia, and Manitoba.

The weevil is a dark-grey snout beetle about 0.2 inch long. It feeds almost entirely on sweet clover, although when forced by hunger will feed to a slight extent on alfalfa. The feeding is characterized by crescent shaped notches in the leaves. At times the plants may be completely defoliated. Such defoliation is particularly destructive to the seedlings. Whole fields may be largely destroyed before the plants are sufficiently established to withstand the injury. The larvae feed upon the sweet clover rootlets but apparently cause slight damage.

First recorded in North Dakota along the northern border in 1941 the weevils spread over the entire state in the course of 2 years with the result that sweet clover almost entirely disappeared from roadsides and waste places and the acreage under cultivation some years dropped to 25 per cent or less of its former status. Practically the same situation has occurred in other areas which the weevil has invaded. While the competition of other crops may have had a minor role in the decline of this valuable pasture and soil improving plant, it is evident that the sweet clover weevil is largely responsible. The loss of sweet clover is regarded with deep concern by general farming, beekeeping and game conservation interests. Besides being valuable for hay, and soil improvement, sweet clover is an important source of honey. The plants provide excellent cover for upland game. Apparently there is no satisfactory substitute plant for these purposes in the northern plains area.

In most areas invaded by the weevil, sweet clover has on occasion staged a temporary "come-back." In North Dakota sweet clover became fairly common along highways and in fields in 1948 for the first time since the weevils first overran the state. This unusual abundance is attributed largely to the lower population of weevils in the preceding year which accounted for a greater survival of seedlings to develop into a fairly extensive second year growth in 1948. Observations made on fields tended to confirm this view in that the weevils averaged only 11 per

overwintered plant in April 1947 as contrasted with 22 per plant for the same time in 1948. The weevils were then feeding on the new growth as it was breaking through the soil. As the new shoots were breaking the soil surface crust the plants were often severly damaged by the weevils before the growth had appeared above the ground.

Surveys were conducted during the fall of 1946, 1947, and 1948 to determine a possible method of forecasting weevil incidence the following spring. The survey consisted of square foot soil samples taken to a half-inch depth from sweet clover areas. The weevils were separated by means of the Berlese funnel. For the three years the weevils averaged 4.5, 7.8, and 6.25 per square foot respectively or an average of 6.1 per square foot for the three years. The weevils hibernated among the plant residue on the soil surface and in cracks in the ground and were mostly in evidence on the heavier types of soil. The fall survey as an aid to forecasting weevil incidence has favorable possibilities

The insects spread largely by flight. The greatest tendency toward flight dispersal is in spring while there is a scarcity of plant growth. This may be largely a response to the hunger urge. New seedings located near already established fields of sweet clover suffered the greatest damage. Delaying the seeding of sweet clover beyond the third week of June, which usually marks the end of the main egg-laying period results in a fairly normal stand of the plants (Munro 1944) but is contingent on adequate rainfall or soil moisture for the seeds to germinate.

Egg laying begins soon after the weevils start feeding on the first green growth in the spring and most years has continued well into June before tapering off. In 1948 the egg laying continued later. A summary by Leraas[1] of results from 43 pairs of weevils collected at Fargo showed the average daily number of eggs laid per female from April 17 to August 4 as follows:—April 17 to May 14, 7.4; May 15 to June 15, 5; June 16 to July 17, 3.2; and July 18 to August 4, none. The maximum number of eggs laid during a 24 hour period by a female was 68. The egg laying was erratic. Usually the female weevil laid many eggs for a day or two, followed by a few days of apparent rest and feeding when few or none were laid. Bird (1947) of Brandon, Manitoba, reports that 73 isolated pairs laid 29,158 eggs, or an average of 399.4 eggs per female. Despite this high egg laying potential of the females only a small percentage usually hatch and complete their development. Many of the newly hatched larvae die while burrowing in the soil to feed on the rootlets. The larva passes through four instars according to Bird.

The egg is oval and white but gradually changes to a dark color within 24 hours. The eggs are scattered mostly in cracks and crevices among the soil particles near the base of the plants. Under field conditions we have observed them to require 12 to 27 days for incubation, but under greenhouse conditions the usual time is 13 to 14 days. Cool, backward weather delays incubation.

In 1944 larvae of a readily visible stage were observed in the soil at Fargo on June 25, but in 1948 they were not found until July 6. Examination for larvae and, pupae of a 1948 spring seeding showed the following:

Table 1.—Seasonal occurrence of larvae and pupae of sweet clover weevil showing number per 100 plants.

EXAMINATION	LARVAE	PUPAE
July 1	0	0
July 6	45	0
July 30	40	8
August 21	144	32
September 7	4	4
October 28	0	0

Previous years' observations have shown that most of the weevils complete their development and emerge from the soil during the last week of July and the first week of August, but in 1948 the bulk of emergence was delayed until the latter part of August. The delayed emergence of the weevils together with the increased amount of sweet clover in 1948 resulted in only slight to moderate feeding injury to the plants before the weevils went into hibernation.

Field observations made at this station have shown the weevils to be most active in late evening. Leraas records the number of weevils collected in 25 sweeps of a 12 inch collecting net at 2 hour intervals as indicative of weevil activity on the plants

[1] Unpublished thesis, 1948.

on June 10 and 11 as follows: 48 at 6 P.M.; 49 at 8 P.M.; 91 at 10 P.M.; 23 at midnight; 24 at 2 A.M.; 20 at 4 A.M.; 5 at 6 A.M.; 30 at 8 A.M.; and 27 at 10 A.M.

Of the applied measures the insecticides have probably been tested more than other control methods. Experiments conducted at the North Dakota station of late years have shown from 55 to 75 per cent control resulting from the application of DDT 3 per cent or 5 per cent, 5 per cent chlordan dust, or toxaphene 10 per cent dust, or toxaphene spray using the same rate of toxic ingredient per acre. The dusting mixutres were applied at the rate of 20 lbs. per acre. The applications made in the latter part of April were more effective than those applied later in the season. Other insecticides including benzene hexachloride (1 per cent gamma), barium fluosilicate, DDD, calcium arsenate, paris green dusts and parathion 1 per cent, were less effective in the order listed. Application of insecticides in early September prior to the insects entering hibernation, has shown no significant control as was indicated by examination of the treated areas the following spring, neither has the application of insecticides to new seedings been effective in control.

Our experience with tillage has closely paralleled that of Bird (1948) showing that shallow tillage in late July after removal of the hay crop of sweet clover which will expose the larvae and pupae to heat and drying is most effective. He reports that this reduces the population as much as 98 per cent and that, where the method had been regularly practiced, the crop was not seriously injured. He also states that it is good agronomic practice, as it provides a partial summer-fallow and destroys weeds.

Our observations have shown that new seedings receive a fair degree of protection from weevil damage when located half a mile or more from the older, established fields of sweet clover, except when weevils are exceedingly abundant and conditions are very favorable for flight dispersal.

The North Dakota station has given some attention to varietal resistance. Based on the feeding notches in 35 trifoliate leaves picked at random from each of 15 varietal plots replicated 4 times at Fargo in early August, a wide variation in the amount of leaf injury was observed. The variety and number of leaf notches occurring were as follows: Grundy County 26.5; Melana 32.5; Erector 32.7; Evergreen 34.0; Hubam 40.8; Brandon Dwarf 48.5; Albotrea 52.5; Aura 56.2; Pioneer 67.5; Early yellow 68.5; Alpha 69.8; Iowa late white (No. 2) 79; Iowa late white (No. 1) 82.5; Wisconsin late white 89; and Saugamon 94.9. The foregoing shows a wide variation in leaf injury. Whether varietal resistance would be of value when few varieties are grown and the insects have little choice has not been determined.

Of the various natural control agencies it was found by Telford & Munro (1944) that the plains toad, *Bufo cognatus* Say, fed greedily on the weevils. The study of the stomach contents of 74 toads taken from sweet clover fields showed that 59 per cent of the insects and other arthropods in their diet were sweet clover weevils At times, a naturally occurring fungus has been observed to kill a few weevils in North Dakota. Allison (1945) of Wisconsin suggests that the weevil has a weak stage in its life history which makes it especially vulnerable to attack by the parasite fungus. Possibly the fungus responsible for this natural control may not develop satisfactorily until after the weevils have been established in an area for a few years, or when moisture conditions are suitable.

In 1948 through cooperation with the Bureau of Entomology and Plant Quarantine, two species of parasites of the sweet clover weevil were introduced from France for propagation and release in infested fields in the Fargo vicinity. They are *Microctonus aethiops* Nees, a braconid, and *Campogaster exigua* (Meig), a small, tachinid. Dr. H. L. Parker, who supervised collecting the parasites in France reported that about 4 per cent of the weevils taken in the collections were parasitized with *M. aethiops* as contrasted with 20 per cent to 50 per cent parasitized by *C. exigua*. Some progress has already been made in the establishment of *M. aethiops* as indicated by the recovery of adults from the first brood at the North Dakota station. Recovery of *C. exigua* progeny has not been made but will be watched for in 1949. According to Munro & Post (1948), even though the weevils on this continent have apparently been separated from their parasites since at

least 1924 (24 annual generations of the weevil), they immediately indicated fear when exposed to *M. aethiops*. The presence of *C. exigua* in the cages did not cause any observable disturbance of the caged weevils.

To what extent the recently imported parasites are able to check the weevils remains to be seen. As yet the application of insecticides to the early spring growth, shallow cultivation to destroy the larvae in the soil, delayed seeding, locating new seedings a half a mile or more from weevil infested fields, and the use of varieties least attractive to the weevils possibly offer the greatest possibilities in applied control in the order named.

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Factors Affecting the Resistance of Certain Cucurbits to the Squash Borer[1]

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Variations in infestation and injury among the cultivated varieties of squashes and pumpkin of the genus *Cucurbita* by the squash borer, *Melittia cucurbitae* (Harris), have been reported. Allen (1938) observed that in adjacent plantings of hubbard and acorn squash, the former variety was seriously damaged while the latter was capable of producing a crop. At Geneva, New York, in 1946 Carruth & Hervey (1947), growing nine varieties, found the infestation rate varied from none to 38 per cent in untreated checks, and it was suggested that in the case of Dickinson Pumpkin and Butternut squash, with infestation rates of 5 per cent and zero respectively, resistance to the insect was possible. Again in 1947 (Carruth & Howe 1948) at the same locality, three varieties were grown, each representing a separate botanical species: Blue Hubbard, *C. maxima* (L.), Table Queen, *C. pepo* (Duchesne) and Butternut, *C. moschata* (Duchesne). The order of susceptibility by species ranked *maxima*, *pepo* and *moschata*. Resistance in the latter was suggested as the result of a compact woody stem, not well adapted to the feeding habits of the insect. This study, made at Geneva, N. Y., during the summer of 1948, reports more detailed information regarding the nature and degree of differential susceptibility of the three species previously mentioned.

In the present study the factors contributing toward resistance were examined under three main interrelated characteristics which constitute the basis for most cases of plant resistance to insect attack. These are: the *preference* of the insect as to oviposition, food or shelter; *antibiosis*, or the adverse effect of the host plant on the biology of the insect; and *tolerance*, or the ability of the plant to repair, recover or withstand infestation (Painter 1941). These factors are frequently modified by various ecological conditions and genetic factors. Thirteen varieties, representing three botanical species, were grown in each of two plots, located about a mile apart. Rows were randomized and each hill consisted of approximately three plants. Plot I, being nearer previous plantings of squash, had a heavier infestation and was more suitable for a study of ovipositional prefer-

[1] New York State Agricultural Experiment Station Journal Paper No. 792 January 7, 1949.

[2] The writer wishes to express appreciation to Dr. L. A. Carruth, under whose direction this work was conducted, for suggestions and assistance received.

ence than plot II, which was used for studying larval populations and antibiosis.

OVIPOSITION PREFERENCES.—On July 14 and 15, shortly after the period of maximum oviposition, each plant in plot I and the ground immediately surrounding each stem base was carefully examined for eggs. The female moths appeared to exert both varietal and specific discrimination in selecting plants for oviposition. Notably, *moschata* varieties received fewest eggs while the *pepo* varieties appeared to be more frequently preferred for oviposition. Although *maxima* varieties were attractive, they were somewhat less so than the *pepo* varieties studied. These observations are summarized in Table 1.

Significant variations in ovipositional preference were apparent between varieties of *Cucurbita pepo.* Taxonomically this species is highly variable, and attempts to make a satisfactory botanical classification have been unsuccessful because of intergradation of morphological characters (Tapley *et al.* 1937). These workers indicate that long before colonization by white man, *C. pepo* probably spread from its original home in Tropical America into what is now southern United States. This suggests the possibility that *C. pepo* may well have been a native host plant of the squash borer in North America.

No consistent correlation was observed between site of oviposition and plant variety or species, although eggs were found in many different locations. Worthley (1923) observed that certain individual moths appeared to exercise discrimination in selection of sites for oviposition, while others did not. This worker reported that in two localities in Massachusetts a tabulation of the location of 1447 eggs laid during two seasons showed 70.4 per cent were on the stem, 26.8 per cent on the leaf stalk and 2.8 per cent on the leaves. In the present study, eggs were frequently found off the plant, especially on the undersurfaces of stones, clods of earth, and in soil cracks near the plant stem. On several occasions females were observed to oviposit at such sites. In one case a single female placed four eggs on the underside of a small earthen clod. In all cases the locations were slightly damp and well protected from sunlight. Table 2 shows locations of eggs found. No correlation between location of eggs and plant species or variety was evident. Many females seeking plants for oviposition avoided the *Cucurbita moschata* varieties, frequently without coming into actual contact with the plants.

ANTIBIOSIS.—On August 16, after nearly all eggs had hatched and before full-grown larvae had migrated to the soil, larval infestation counts were made. The basal three feet of each plant in the even numbered hills were carefully examined for entry lesions, frass and larval tunneling. Stem tissues were dissected where necessary. The number, stage and location of larvae in each plant were recorded. These observations are summarized in Table 3.

The complete absence of squash borer larvae in varieties of *C. moschata* in plot II provides strong evidence that this

Table 1.—Squash borer eggs observed on species and varieties of *Cucurbita* on July 14–15, 1948, shortly after peak oviposition period. Ten hills examined for each variety.

SPECIES	VARIETY	PER CENT OF PLANTS WITH EGGS	EGGS PER 100 PLANTS
C. maxima	Blue Hubbard	47	100
	Boston Marrow	49	106
	Golden Delicious	50	95
C. pepo	Early Summer Crookneck	71	287
	White Bush Scallop	50	113
	Connecticut Field Pumpkin	48	145
	Small Sugar Pumpkin	69	172
	Table Queen	85	208
C. moschata	Butternut	29	55
	Green Striped Cushaw	30	61
	Dickinson Pumpkin	15	23
	Sweet Cheese Pumpkin	24	52
	Sweet Potato Pumpkin	21	24

Table 2.—Location of squash borer eggs deposited on or near plants of 18 varieties of Cucurbita, July 14–17, 1948.

	NUMBER OF EGGS		PER CENT OF TOTAL	
Found on plants:	474		73.2	
stem		417		64.5
leaf stalk		47		7.3
leaves		7		1.1
misc.		3		0.2
Found near plants[1]	172		26.7	
in soil (including clods)		149		23.3
on stones		22		3.4
in organic debris		1		1.0

[1] Includes some eggs which were dislodged from plants by weathering, etc.

Table 3.—Susceptibility of species and varieties of *Cucurbita* to squash borer infestations and injury, 1948.

Species	Variety	Six Even Hills—Examined Aug. 16			Six Odd Hills—Examined Sept. 28		
		Plants examined	Larvae per 100 plants	Per cent plants infested	Plants examined	Per cent plants infested	Per cent plants severely injured[1]
C. maxima	Blue Hubbard	13	38	38	13	62	46
	Boston Marrow	14	36	29	14	53	21
	Golden Delicious	12	50	42	17	43	35
C. pepo	Summer Crookneck	18	33	33	18	33	0
	White Bush Scallop	18	67	56	16	50	0
	Connecticut Field Pumpkin	15	33	33	18	39	11
	Small Sugar Pumpkin	11	55	37	12	39	17
	Table Queen	16	56	38	—	—	—
C. moschata	Butternut	18	0	0	18	0	0
	Green Striped Cushaw	18	0	0	15	0	0
	Dickinson Pumpkin	18	0	0	17	0	0
	Sweet Cheese Pumpkin	18	0	0	17	0	0
	Sweet Potato Pumpkin	18	0	0	16	0	0

[1] Plants with more than half of basal stem tissues severed.

species is inherently unfavorable for proper larval development. Further evidence of the differential antibiotic behavior between *Cucurbita moschata* and *C. pepo* was provided by artificial infestation experiments on the varieties Butternut (*C. moschata*) and Table Queen (*C. pepo*). On July 21, six hills of each variety were artificially infested with an average of 3.6 eggs per plant. Eggs were obtained from nearby garden plots. The transfer was accomplished by removing a thin slice of stem tissue beneath the egg and shortly thereafter re-attaching the entire piece with 5 per cent methyl cellulose solution[1]

Table 4.—Data concerning plant entry and survival of squash borer larvae originating from artificial infestations of eggs on two squash varieties, 1948.

	Table Queen (*C. pepo*)	Butternut (*C. moschata*)
Plants infested artificially	17	15
Eggs added July 21[1]	64	54
Stem entries July 31	20	5
Average distance from plant base	1.5"	5.1"
Leaf stalk entries July 31	9	5
Average distance from plant base	5.5"	7.2"
Total larval entries July 31	29	10
Surviving larvae found August 19	17	2
Per cent survival after entry	59	20

[1] No naturally oviposited eggs were observed at the time artificial infestations were made, although on August 18 counts of surviving larvae in six adjacent hills of each variety which were not artificially infested revealed nine larvae in Table Queen but none in Butternut. This natural surviving infestation in Table Queen was at the rate of 0.56 larvae per plant as compared with 1.06 larvae per artificially infested plant.

to the stem base of the new host plant. Before artificial infestations of eggs were made, each plant involved was carefully examined for naturally oviposited eggs. Although very few may have been present, none were found. On July 13, 10 days after artificial infestation, 96 per cent of the eggs had hatched. At this time each plant was examined to determine the number and location of larval entries. Frass extruding from a small hole bored into the tissues was assumed to indicate an entry. Larvae were not disturbed by this examination. The study of this phase was concluded by making larval counts on both the artificially infested plants and check plants on August 18. These observations, summarized in Table 4, also suggested the presence of a greater antibiotic effect in Butternut (*moschata*) than in Table Queen (*pepo*).

The records indicate that in Butternut a smaller percentage of newly hatched larvae were able to enter the plant tissues, a higher proportion entered the more tender leaf stalks, larvae traveled a greater distance before entry into plant tissues, and larval survival after entry was lower (20 per cent) than in Table Queen (59 per cent), a less resistant variety. It is believed that both nutritional and mechanical factors may contribute to this antibiotic effect. Butternut apparently provided insufficient food of a

[1] "*Methocel*," manufactured by Dow Chemical Company.

suitable nature and larval growth and development were also retarded by the small stems containing only a comparatively small amount of parenchyma and a higher proportion of tough, ligneous vascular bundles. The proximity of the inner vascular bundles to each other provided a barrier to larval entry into the medullary cavity. Larvae were not observed to penetrate this inner ring of bundles in Butternut. Older and more vigorous larvae feeding on the more abundant parenchyma in Table Queens stems were capable of cutting these bundles. Figure 1 indicates differences in stem structure between the plant species studied. Mortality of larvae infesting both varieties occurred most frequently during the first instar. Two larvae which survived in Butternut reached the second instar but were stunted, weak, and lacked the creamy white color of normal larvae.

Varied environmental conditions altered the apparent resistance of the squash varieties to borer attack. In the field the prolonged exposure of young larvae outside the stems of the less desirable varieties undoubtedly contributed to the high mortality before entry. Dead first instar larvae were frequently found on the stems of nearly all varieties. In artificial infestations of potted plants in the insectary, where exposure to predators and adverse climatic conditions was less severe, nearly as many larvae penetrated the outer stem tissues of Butternut as Table Queen. Observations in the field indicated little or no migration of first instar larvae from one hill to another.

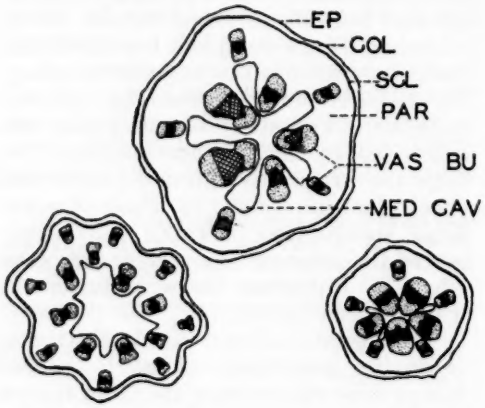

FIG. 1.—Diagrammatic transections of 3 to 4 week old, freshly cut squash stems showing differences in gross anatomy, size, vascular bundle distribution and tissue proportions. All drawn to same scale.

EP—epicotyl, COL—collenchyma, SCL—sclerenchyma, PAR—parenchyma, VAS BU—vascular bundles, and MED CAV—medullary cavity.

Lower Right—Butternut (*Cucurbita moschata* Duchesne.) Most resistant.

Lower Left—Table Queen (*C. pepo* L.). Vining type. Moderately resistant.

Upper Figure—Blue Hubbard (*C. maxima* Duchesne). Least resistant.

DIFFERENTIAL PLANT TOLERANCE.—To study plant response to larval attack, a final infestation survey was made on September 28 on the remaining untouched odd hills of plot II. The number of infested plants and the number with severely damaged stem bases were recorded. When more than one-half the stem tissues were severed, the plant was classed as severely damaged. Stem tissues no longer viable because of bacterial or fungus rot were considered severed, since such a condition is believed to be the direct result of borer infestation.

The *maxima* varieties were less capable of withstanding infestation than *pepo* varieties (Table 3), though larval populations in the latter were equal or in some cases greater. Examination of stem bases of *maxima* varieties revealed greater injury, due less to increased borer activity than to necrosis of tissues caused by rot organisms following borer infestations. The normal secondary growth of parenchymatous tissues in the stem base (Hayward, 1938) was greatly accelerated after borer infestation, especially in the *maxima* varieties. In vigorous plants, the infested stem base frequently became enlarged, occasionally reaching two inches in diameter This natural plant response permitted the plant to support more larvae, although this was offset by the increased susceptibility of the swollen parenchyma tissue to rot organisms. The outer stem tissues, including the tough protective sclerenchymatous ring, did not keep pace with the increased growth of the parenchyma and became ruptured longitudinally, thus exposing the inner tissue to decay organisms. As the rot progressed, only the stringy vascular system remained, resulting in the "shredded" stem condition mentioned in the literature. The thick, short stems of the *C. pepo* bush varieties provided more ample parenchyma tissue for borer development and were capable of supporting more larvae than *maxima*, with less injury. Larval injury in the smaller stemmed vining *pepo* varieties was greater than in

Table 5.—Infestations of squash bugs and cucumber beetles on foliage of different species and varieties of *Cucurbita*, 1948.

Species and Variety	Infestations per 10 Hills			
	Squash bug		Cucumber beetles	
	Egg masses[1] July 29	Nymphs and adults Aug. 21[2]	Striped Aug. 21[2]	Spotted Aug. 21[2]
C. maxima				
Blue Hubbard	49.0	118.0[3]	19.0	7.0
Golden Delicious	19.1	55.5	50.0	5.5
Boston Marrow	21.8	29.1	40.9	5.5
C. pepo				
Connecticut Field Pumpkin	7.5	6.7	41.6	8.3
Small Sugar Pumpkin	2.0	2.0	22.0	8.0
Early Summer Crookneck	5.0	3.0	45.0	3.0
Early White Bush Scallop	6.7	1.1	101.0	15.5
Table Queen	4.6	0.0	27.2	7.3
C. moschata				
Butternut	1.7	0.0	5.0	0.0
Green Striped Cushaw	6.7	0.0	15.0	5.0
Dickinson Pumpkin	0.0	0.0	7.5	0.0
Large Sweet Cheese Pumpkin	1.7	0.0	20.0	5.0
Sweet Potato Pumpkin	2.5	1.7	19.2	5.0

[1] On 10 center leaves of each hill.
[2] August 21 counts were of the individuals within a 1-foot radius of the center of each hill examined.
[3] Foliage badly damaged.

the *pepo* bush varieties because the smaller food supply of the former necessitated consumption of a greater proportion of the stem by the larvae. All *pepo* varieties were less susceptible to rot organisms.

Results from breeding the species *maxima*, *pepo*, and *moschata* suggest that a type of *moschata*, or a closely allied form, is the primitive type of the annual *Cucurbita* (Tapley *et al.* 1937). This may be another instance in which the plant type exposed to the attack of an insect for the longest time may be the most resistant. The squash borer and other species of *Melittia* are abundant in regions of tropical America where the annual species are said to have originated.

OTHER INSECT PESTS.—The greater amount of borer injury to Blue Hubbard as compared with the two other *maxima* varieties may be partially attributed to decreased vigor caused by a heavy squash bug infestation. Comparative infestations by the squash bug, *Anasa tristis* (Deg.) and cucumber beetles, *Diabrotica vittata* (F.) and *Diabrotica duodecimpunctata* (F.), are shown in Table 5. The squash bug favored *maxima* for both oviposition and feeding and Blue Hubbard was especially preferred. Squash bug migration toward *maxima* probably occurred, since oviposition on *pepo* and *moschata* provided initial populations greater than were reflected by subsequent nymphal counts. *Moschata* was least attractive to infestation by all three insect species. White Bush Scallop (*pepo*) was especially attractive to cucumber beetles.

SUMMARY.—At Geneva, New York, in 1948, two plots with plantings of 13 varieties of squash and pumpkin belonging to 3 species of cultivated *Cucurbita*, *C. maxima* Duchesne, *C. pepo* L., and *C. moschata* Duchesne, revealed marked differences in resistance to attack by the squash borer, *Melittia cucurbitae* (Harris). Studies were concerned with oviposition preferences, differential larval populations, artificial infestation of plants in the field and insectary, differential injury observations and observation of population levels of associated insect pests.

At the insect populations prevailing, all five *moschata* varieties (Butternut, Green Striped Cushaw, Dickinson Pumpkin, Large Sweet Cheese Pumpkin, and Sweeet Potato Pumpkin) were highly resistant to borer attack apparently because of avoidance by ovipositing moths and a low rate of larval establishment. These *moschata* varieties were characterized by hard, compact, woody stems, with closely

ranged, tough vascular bundles and an apparently inadequate food supply for normal larval development.

All three *maxima* varieties (Blue Hubbard, Golden Delicious and Boston Marrow) were relatively susceptible to borer attack because of moderately high attractiveness for oviposition, larval entry and development. These varieties were also particularly susceptible to infections by organisms causing stem decay.

Three trailing vine *pepo* varieties (Table Queen, Connecticut Field, and Small Sugar) were moderately resistant because of partial compensation for high ovipositional preference by moderate antibiotic influences of plant tissues on larval development, resistance to the development and spread of rotting organisms and moderate tolerance to attack.

Two *pepo* bush varieties (White Bush Scallop and Early Summer Crookneck) appeared higher in borer resistance than the vining varieties of the same species. In this case higher ovipositional preference and lack of antibiotic influences toward larvae were largely offset by a high tolerance to insect attack, created by the presence of an abundance of succulent tissue in large, fast-growing stems.

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Wireworm Control with Several Insecticides Introduced into the Soil

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The control of wireworms on potatoes, particularly of the eastern field wireworm, *Limonious agonus* (Say), has presented a perplexing problem. Cultural control methods, while effective for the wheat wireworm, *Agriotes mancus* (Say), have met with little success for the Eastern field wireworm. Such methods have also proven to be inconvenient to growers; consequently there has been considerable interest in finding a means of chemical control. The use of benzene hexachloride as a soil insecticide has stimulated renewed interest in the approach to this problem. This insecticide has been used to a considerable extent experimentally, and to a lesser degree commercially, with good success from a purely control standpoint, but other problems have arisen, which limits the usage of benzene hexachloride.

Greenwood (1947), working with potatoes, reported that good control of wireworms was obtained by the use of crude benzene hexachloride at concentrations as low as 0.2 pound of gamma isomer per acre. At the same time Pepper, *et al.* (1947) also working with potatoes, obtained excellent control of wireworms with the use of crude benzene hexachloride at levels of 2–10 pounds of gamma isomer per acre. In 1947 Greenwood (1948) included chlordan and toxaphene in his tests on wireworms. Chlordan gave control equal to or better than that obtained with crude benzene hexachloride, but toxaphene was ineffective. Unfortunately, the problem has not ended with these findings for in dispensing with the pest a new and serious problem has been introduced. This is the problem of off-flavor, which is imparted to potato tubers by the use of these insecticides and is at times so objectionable as to prevent their consumption.

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Investigations in the use of crude benzene hexachloride for wireworm control have been in progress for the past two seasons. In addition to this material, other insecticides tested were chlordan, toxaphene, heptachlor, compound 118, and the refined product of benzene hexachloride in which impurities thought to be responsible for off-flavor were eliminated.

TREATMENTS AND METHODS.—Concentration series of three insecticides, crude benzene hexachloride at 0.125, 0.25, 0.50, 1.0 and 2.0 pounds of gamma isomer per acre, chlordan at 2, 4, 8, and 16 pounds per acre, and toxaphene at 2, 4, 8, and 16 pounds per acre, were tested in up-state New York during the 1947 season. Five insecticides, crude and refined benzene hexachloride at 0.5, 1.0, and 2.0 pounds of gamma isomer per acre, chlordan at 2, 4, and 8 pounds per acre, heptachlor[1] at 0.5, 1.0, 2.0, 4.0 and 8.0 pounds per acre, and compound 118[2] at 2 and 4 pounds per acre were tested in the same area during the 1948 season. These tests were made in soils of various types infested with either the wheat wireworm or the eastern field wireworm.

The insecticides were diluted to standard concentrations with either pyrophyllite or talc, the former possessing more optimum physical qualities for application. Diluted dusts were applied in the Spring at the various rates of application to land previously fitted for planting. They were applied to the soil surface by means of a hand fertilizer spreader. Following application the land was harrowed in two directions with a disc or spring-toothed harrow. This insured a thorough mixing of the toxicant in the top 4 or 5 inches of soil.

Treatments were replicated three or four times in randomized blocks; the plots having areas of either 0.02 or 0.01 acres. One hundred tubers were random-selected for sampling from the four centre rows of each plot. These tuber samples were washed thoroughly to facilitate inspection for wireworm injury. Injured tubers were placed in one of three categories—slight, moderate or severe. Tubers classified as slight had only one apparent wireworm puncture, moderate two to five punctures, and severe six or more punctures. Only punctures 0.25 inches in depth were recorded and where there was doubt as to the cause of injury it was considered as being caused by means other than wireworms. In the summary tables total injury and the combined moderate and severe categories are listed. The latter approximates the percentage of tubers that would not make the U. S. No. 1 grade.

RESULTS AND DISCUSSION.—The results of the 1947 field experiments are given in table 1. Wireworm infestations were not particularly heavy during this season but could be classed as moderate in intensity. Applications of 0.125 and 0.25 pounds of gamma isomer of crude benzene hexachloride, while materially reducing the incidence of injury, cannot be considered as giving effective control. Applications of 0.50 and 1.0 pounds of the gamma isomer content of crude benzene hexachloride gave good control in all cases, while 2.0 pounds of gamma per acre gave excellent control. It would appear that under these particular conditions effective control can be obtained with applications of from 0.50 to 1.0 pounds of gamma isomer per acre. Two pounds of gamma isomer per acre is probably excessive and 0.125 and 0.25 pounds of gamma isomer too low a rate of application.

Chlordan appeared to give good control at all rates of application tested, whereas toxaphene gave very poor control and in most cases did not reduce the injury appreciably. This latter insecticide seemed to have no prospects for wireworm control and was eliminated from future tests.

The results of the field experiments for the 1948 season are given in table 2. Wireworm infestations varied from low to fairly heavy in intensity upon the experimental sites.

All rates of application of crude benzene hexachloride gave good control and there was no significant difference between them. It is quite probable that with such a low infestation of wireworms as in this particular case, 0.50 pound of gamma isomer is adequate.

Refined benzene hexachloride compared favorably with the crude product, although the trend appeared to be that higher concentrations are in order with this material. In experiment 2 the 1 pound application of gamma isomer

[1] Heptachlor—$C_{10}H_5C = C_{10}H_5Cl_7$, technical grade.

[2] Compound 118—1, 2, 3, 4, 10, 10-hexachloro-1:4, 5:8 diendomethano—1, 4, 4a, 5, 8, 8a-hexahydronaphthalene, technical grade.

Heptachlor and compound 118 ground to a 50 per cent powder in a Raymond mill.

Table 1.—Field results of wireworm control experiments on potatoes, 1947.

Treatment	Pounds per Acre	Per Cent Wireworm Injury to Potato Tubers									
		Expt. 1		Expt. 2		Expt. 3		Expt. 4		Expt. 5	
		Total	Mod. + sev.	Total	Mod. + sev.	Total	Mod. + sev.	Total	Mod. + sev.	Total	Mod. + sev.
Untreated		36.2	16.3	32.1	13.2	31.5	18.0	33.0	16.8	50.1	36.8
Gamma crude benzene hexachloride	0.125	18.8	7.0								
	0.25	10.0	3.5	14.7	5.3	12.0	5.0				
	0.50	5.3	1.0	6.7	2.3	3.0	1.0				
	1	2.5	0.5	2.3	1.3	1.0	0.0				
	2	0.0	0.0	0.0	0.0	1.0	0.0				
Chlordan	2							4.8	0.8		
	4			3.7	0.3	4.0	0.0	1.5	0.3		
	8			2.0	0.7	3.0	1.0	1.3	0.5		
	16			2.0	0.3			1.3	0.5		
Toxaphene	2									53.3	36.3
	4			34.0	16.3	61.0	37.0			38.0	26.5
	8			31.0	16.0	14.0	9.0			24.7	13.5
	16			31.3	18.0					31.3	20.5
Least significant difference		4.5		10.2		—		9.5		34.9	

Experiment 1 Penfield, N. Y., Ontario loam, Eastern Field Wireworm
2 Potter, N. Y., Organic soil, Wheat Wireworm
3 Cohocton, N. Y., Mardin gravelly silt loam, Wheat Wireworm
4–5 Spencerport. N. Y., Ontario fine sandy loam, Eastern Field Wireworm

gave poor control. This was unexpected and somewhat of a mystery. There was no apparent reason for such poor control in this case but it did indicate that under some specific conditions, whatever they may be, this material may not give the desired control.

The results of the chlordan applications were of greater interest than those of the benzene hexachloride, as this insecticide was found by Greenwood (1947) to produce less flavor contamination in the potato tubers. There was a definite trend that this material at the 2.0 and 4.0 pound application was insufficient where wireworm infestations were fairly heavy. This is borne out in experiments 2, 3, and 4, but where the infestation of wireworms was on the light side, as in experiments 1 and 5, these concentrations were as effective as indicated in the 1947 experiments. Applications of 8 pounds of chlordan gave consistently good control.

Heptachlor, a close relative of chlordan, gave results superior to chlordan at identical rates of application. Concentration applications of 2.0 and 4.0 pounds per acre of this material gave economical control of wireworms even at high levels of infestation.

The test of compound 118 was very restricted due to a scarcity of this material at the time of application, hence the results are of a preliminary nature. The data from the two experiments which included this compound indicated that promising control may be attained with a dosage of 4 pounds per acre.

The variation of soil types encountered in these experiments did not appear to have any effect on the toxicity of the insecticides to wireworms. There also appeared to be no difference in control of the two wireworm species by the various materials tested.

SUMMARY.—Six soil insecticides, crude benzene hexachloride, refined benzene hexachloride, chlordan, toxaphene, heptachlor, and *compound 118* were tested against the wheat wireworm and the eastern field wireworm during a 2-year period.

Benzene hexachloride gave practical control at 0.5 to 1 pound per acre. However, in one experiment an application of 1 pound of the refined grade of benzene hexachloride was not satisfactory but two pounds per acre produced good results. Toxaphene was found to give very poor control and was not regarded as having promise. Chlordan gave good control at

Table 2.—Field results of wireworm control experiments on potatoes, 1948.

Treatment	Pounds per Acre	Per Cent Wireworm Injury to Potato Tubers									
		Expt. 1		Expt. 2		Expt. 3		Expt. 4		Expt. 5	
		Total	Mod. + sev.	Total	Mod. + sev.	Total	Mod. + sev.	Total	Mod. + sev.	Total	Mod. + sev.
Untreated		28.8	15.8	44.3	29.8	53.3	33.0	66.9	51.4	33.7	16.7
Gamma crude benzene hexachloride	0.5	1.8	0.5								
	1	1.0	0.5								
	2	0.3	0.3								
Gamma refined benzene hexachloride	0.5	3.3	0.3								
	1	4.8	0.8	31.8	21.3						
	2	1.0	0.0	3.8	1.3						
Chlordan	2	3.0	1.0	14.0	7.8	19.3	12.3	15.5	6.2	9.3	3.3
	4	1.8	0.3	10.8	5.3	15.3	8.0	5.1	3.3	8.0	2.0
	8	1.3	0.3	2.5	0.8	6.0	3.0	2.0	0.4	3.7	1.0
Heptachlor	0.5							11.2	5.1		
	1					12.7	6.3	2.7	0.7		
	2					4.0	1.7	1.6	1.2	4.7	2.3
	4					5.3	2.0			4.3	0.0
	8					0.3	0.0			1.7	0.7
Compound 118	2					16.7	9.0				
	4					3.7	1.3			2.7	0.7
Least significant difference		4.2		21.8		11.8		6.5		7.5	

Experiment 1 & 3 Ithaca, N. Y., Canfield silt loam, Wheat Wireworm
Experiment 2 West Henrietta, N. Y., Ottawa loamy fine sand, Eastern Field Wireworm
4 Medina, N. Y., Berrien fine loamy sand, Eastern Field Wireworm
5 Penfield, N. Y., Genessee fine sandy loam, Eastern Field Wireworm

2 to 4 pounds per acre where wireworm infestations were light, but under heavy infestations 4 to 8 pound applications were required. Heptachlor gave good control at 2 to 4 pounds per acre. Preliminary results with *compound 118* indicated considerable promise with this material for wireworm control.

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H. H. RICHARDSON IN ARGENTINA

Dr. Henry H. Richardson of the Bureau of Entomology and Plant Quarantine, located at Hoboken, N. J., was detailed to Argentina for several months beginning in January. His duties will be to organize the facilities and procedures for treating grapes and deciduous fruits originating in areas quarantined because of the Mediterranean and other fruit flies, to permit entry of such fruit into the United States.

Control of Plum Curculio on Peaches with Benzene Hexachloride, Parathion, Chlordan and Lead Arsenate[1]

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General Chemical Division, Allied Chemical & Dye Corp.[2]

A more effective insecticide than either acid lead arsenate or basic lead arsenate is needed for controlling the plum curculio on peaches. Among the newer insecticides tested for this purpose, benzene hexachloride, parathion and chlordan have generally given promising results in comparison with the results obtained with DDT, chlorinated camphene and hexaethyl tetraphosphate (Snapp 1947; Driggers & Darley 1948; Graham 1948; Smith 1948; Stearns & Warren, 1948; Grayson, 1948; Dewey & Van Geluwe 1948; Neiswander 1948; Dean 1948).

The cooperative experiments in control of the plum curculio on peaches begun by the writers in 1947 (Driggers & Darley, 1948) were continued in 1948, and the work was expanded to include tests with parathion, chlordan and DDT, in addition to benzene hexachloride and acid lead arsenate. Field tests were made in southern, central and northern New Jersey. The work in southern New Jersey included a number of special experiments designed to yield additional information on how the various insecticides being used effect plum curculio control. At harvest, samples of fruit from the various field experiments were taken for flavor comparisons.

Field Experiments in Southern New Jersey.—The writers pooled their equipment and manpower to set up and run an extensive series of spray plots in a 10-acre orchard of 6-year-old trees at Glassboro. This orchard is surrounded by ideal hibernating quarters for adult curculios and has been subject to heavy attacks annually since it came into bearing.

Twenty-one different curculio spray programs were tested. Each program was applied on five 2-tree plots replicated in randomized blocks. Two blocks consisted of the variety Sun High, two of Summercrest, and the fifth of a mixture of the two. The basic spray schedule used comprised three applications made at approximately 10-day intervals, beginning when the husks were three-fourths off (*i.e.*, May 10, May 20 and June 2). The 17 programs tested according to this schedule included 13 employing benzene hexachloride spray powders and differing as regards brand, percentage and degree of refinement of gamma isomer, dosage and use of spray coverage supplements, and one each employing parathion and chlordan spray powders, acid lead arsenate plus DDT spray powder and, as the standard-of-comparison, acid lead arsenate. Among the other four programs tested, one employed a benezene hexachloride spray powder in four applications made at 7-day intervals (May 10, 17, 24, and 31) and the others employed benzene hexachloride, parathion and chlordan spray powders in five applications made at approximately 10-day intervals (May 10 and 20, June 2, 12 and 19) to determine the effect of two extra 10-day applications of these insecticides on control and to accentuate any possible impairment of flavor in the harvested fruit owing to their use.

The degree of control given by the various spray programs tested was determined mainly by collecting and examining (cutting open) all dropped peaches for each test tree at approximately weekly intervals from May 25, when wormy fruits first began to drop, to July 15, when drop of curculio-wormy fruits had practically ceased. All fruits evidencing internal injury by plum curculio larvae were recorded as "wormy." The results of these numerous examinations of dropped peaches are summarized cumulatively for the season in table 1 for the various spray programs used, which are listed in the apparent order of their efficiency in reducing plum curculio reproduction during the season.

Referring to the data in table 1, the results given by two programs are obviously anomalous and indicate that the randomized block plot layout used was not entirely successful in minimizing the effect of unevenness in the curculio attack. That is, programs 1 and 11 should have given better control than programs 16 and

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

[2] The writers had the valuable assistance of Messrs. R. L. Pierpont, Leland G. Merrill, Jr., and Alvin Magee, and Dr. A. E. Foster, in carrying out the work reported.

20, respectively. However, it is believed that the data in table 1 show that, among the 17 programs comprising three applications at 10-day intervals, the 13 employing benzene hexachloride spray powders (at dosages providing the gamma isomer of benzene hexachloride at 0.09 to 0.24 lb. per 100 gals.) gave control as good as to appreciably better than parathion (at 0.25 lb. to 100 gals.), considerably better control than chlordan (at 1 lb. to 100 gals.), and very much better control than acid lead arsenate (at 2 lbs. to 100 gals.) with or without DDT. In turn, at the dosages noted, parathion gave considerably better control than chlordan, and the latter much better control than acid lead arsenate with or without DDT. The efficiency of acid lead arsenate was only moderately increased by use with it of DDT (1 lb. to 100 gals.).

Similarly, among the three programs comprising five 10-day applications, benzene hexachloride (0.18 lb. gamma isomer to 100 gals.) gave better results than parathion (0.25 lb. to 100 gals.) and both of these much better results than chlordan (1 lb. to 100 gals.) and somewhat better results than their use at the same dosages in three 10-day applications. Use of benzene hexachloride (0.18 lb. gamma isomer to 100 gals.) in four 7-day applications gave control similar to that from its use in five applications at intervals of 10 days.

The differences in control obtained with the 15 different benzene hexachloride programs compared are not statistically significant but, in the main, appear to be reasonably attributable to differences in dosage of gamma isomer, interval between applications and number of applications. These data also indicate that the efficiency of benzene hexachloride spray powders in controlling the plum curculio is increased by reducing particle size or by use of suitable spray coverage supplements. The data do not show any significant differences in efficiency among the various benzene hexachloride spray powders used attributable to differences in brand or in percentage or degree of refinement of the gamma isomer.

FIELD EXPERIMENTS IN CENTRAL NEW JERSEY.—Benzene hexachloride, parathion, chlordan and acid lead arsenate plum curculio spray programs were also compared in a central New Jersey peach orchard in 1948. Curculio control in this orchard had not been a serious problem for several years and, during this period, the grower had been able to avoid undue crop loss owing to this pest by practicing border spraying only. For this reason it was feasible to include an unsprayed check plot in these tests.

Each plot consisted of a 4 by 12 block

Table 1.—Spray programs tested, number of curculio-wormy dropped peaches per tree and percentage reduction in curculio reproduction compared with standard program.

Plot No.	Spray Materials Used per 100 Gallons[1] (Plus Wettable Sulfur 4 Lbs. in Each Spray)	Through 6/19 Rank	Through 6/19 Wormy Drops	Through 6/25 Rank	Through 6/25 Wormy Drops	Final 7/15 Rank	Final 7/15 Wormy Drops	Final Per Cent Reduction
14	"A"[2] Benzene hexachloride (6% gamma) 4 lbs.	2	1.1	1	3.4	1	5.9	96.7
17	"A" Air Milled Benzene hexachloride (6% gamma) 3 lbs.	5	3.3	5	4.8	2	7.9	95.6
10	"A" Benzene hexachloride (6% gamma) 3 lbs. (5 10-day sprays)	4	2.3	4	4.5	3	8.9	95.0
5	"B" Benzene hexachloride (10% gamma) 2 lbs.	1	1.0	2	4.0	4	9.0	95.0
19	"A" Benzene hexachloride (6% gamma) 3 lbs. (4 7-day sprays)	3	1.4	3	4.2	5	9.5	94.7
3	"C" Benzene hexachloride (6% gamma) 3 lbs.	8	3.8	8	7.2	6	10.0	94.4
18	"A" Air Milled Benzene hexachloride (6% gamma) 2 lbs.	6	3.4	7	6.9	7	10.2	94.3
15	"A" Impregnated purified gamma benzene hexachloride (5%) 3.6 lbs.	11	5.5	10	8.6	8	10.4	94.2
16	"A" Benzene hexachloride (6% gamma) 2 lbs.	7	3.4	6	6.6	9	10.8	94.0
8	"B" Benzene hexachloride (25% gamma) ½ lbs.	12	6.1	11	8.9	10	13.9	92.3
12	Parathion (25%) 1 lb. (5 10-day sprays)	15	8.0	14	11.8	11	13.9	92.3
2	"D" Benzene hexachloride (6% gamma) 3 lbs.	10	4.6	12	9.3	12	15.5	91.4
7	"A" Benzene hexachloride (6% gamma) 1.5 lbs. *Colloidal Z-1* 4 oz.	13	6.4	13	9.9	13	15.5	91.4
1	"A" Benzene hexachloride (6% gamma) 3 lbs.	9	4.1	9	8.1	14	16.8	90.7
4	"C" Benzene hexachloride (12% gamma) 1.5 lbs.	16	10.1	16	14.8	15	21.4	88.1
6	"B" Benzene hexachloride (10% gamma) 1 lb. Spreader 1 pt.	14	7.9	15	13.8	16	23.2	87.1
21	Parathion (25%) 1 lb.	17	11.8	17	18.3	17	26.9	85.0
20	Chlordan (40%) 2.5 lbs.	18	39.8	18	44.8	18	48.5	73.0
11	Chlordan (40%) 2.5 lbs. (5 10-day applications)	19	49.3	19	54.3	19	57.3	68.1
9	Standard Lead Ars. 2 lbs., hyd. lime 12 lbs. Zinc. Sulf. 5.5 lbs., DDT (50%) 2 lbs.	20	108.7	20	120.0	20	126.7	29.5
13	Standard Lead Ars. 2 lbs., hyd. lime 16 lbs.	21	145.2	21	166.0	21	179.7	0.0

[1] In three 10-day applications, except where otherwise noted.
[2] The letters A to D designate the four different brands, *i.e.* manufacturers, of the various benzene hexachloride spray powders used.

of trees of several varieties. Two curculio spray applications were made, one at the shuck-off stage (May 19 to 21) and the other 10 days later. Control was determined by the procedure used in the southern New Jersey tests discussed above, using 6 count trees in each plot. The spray materials used and results obtained are given in table 2.

However, in these tests, chlordan reduced curculio reproduction very much less in comparison with the other insecticides than in the other field tests conducted under heavy infestation conditions in southern New Jersey, whereas benzene hexachloride and parathion gave similar results in both of these experiments.

SPECIAL EXPERIMENTS IN SOUTHERN NEW JERSEY.—Data obtained by the writers in 1947 (Driggers & Darley, 1948) strongly indicated that under field conditions benzene hexachloride, at dosages providing up to 0.18 lb. of gamma isomer per 100 gallons applied at intervals of 7 to 10 days, affects plum curculio control mainly by killing the immature stages infesting the fruits and probably kills but few of the adults present. Efforts were continued in 1948 to determine how some of the new insecticides reduce plum curculio reproduction under actual field conditions. The first experiment carried along these lines in 1948 involved placing cheesecloth sheets under single trees in each of 9 of the 21 southern New Jersey spray plots the day before the second spray application was made, collecting the adult curculios found on these sheets daily after application of the second spray and for 10 days after application of the third spray, and making other adult population counts

Table 2.—Plum curculio control. Central New Jersey experiments.

Plot No.	Materials per 100 Gals.[1]	Dropped Fruits per Tree		% Reduction Compared With:	
		Total	Wormy	Check	Std. L.A.
1	Benzene Hexachloride (6% gamma) 3 lbs.	941	0.7	99.8	98.8
2	Parathion (25%) 1 lb.	1014	1.7	99.5	97.1
3	Check (no spray)	1308	317.0	0.0	
4	Acid Lead Ars. 2 lbs., Hydrated lime 16 lbs.	587	57.7	81.8	0.0
5	Chlordan (40%) 2.5 lbs.	589	14.3	95.5	75.2

[1] Plus wettable sulfur 4 lbs. to 100 gals. in both applications made.

The data in table 2 show that remarkably nearly complete control of the plum curculio was obtained with benzene hexachloride and parathion as used in this field test. Otherwise, the results obtained agree very well with those obtained in the southern New Jersey experiment with the same insecticides at the same dosages.

FIELD EXPERIMENTS IN NORTHERN NEW JERSEY.—The four insecticides used on the central New Jersey plots were again compared in a Warren County peach orchard. Plum curculio control has been a serious problem in this orchard for several years and, for this reason, the grower was understandably unwilling to allow use of an unsprayed check plot. Each of the four programs compared was applied on a plot three rows wide running across rows of four varieties, and each consisted of two applications made May 29 (shuck-off) and June 9. The remainder of the test block was sprayed with benzene hexachloride for curculio control by the grower. Control data, taken as described in the previously discussed tests, using six count trees in each plot, are given in table 3.

The results obtained in northern New Jersey are nicely in line with those obtained in southern and central New Jersey in that the order of efficiency of the insecticides compared was again benzene hexachloride (0.18 lb. gamma isomer in 100 gals.), parathion (0.25 lb.), chlordan (1 lb.) and standard lead arsenate (2 lbs.).

Table 3.—Plum curculio control. Northern New Jersey experiments.

Plot No.	Materials Per 100 Gallons[1]	Dropped Fruits Per Tree		Per Cent Reduction Compared With Std. Lead Arsenate
		Total	Wormy	
1	Benzene Hexachloride (6% gamma) 3 lbs.	429	18.3	92.2
2	Chlordan (40%) 25 lbs.	383	195.0	15.5
3	Acid Lead Arsenate 2 lbs. Hydrated lime 16 lbs.	520	233.3	0.0
4	Parathion (25%) 1 lb.	422	27.7	88.1

[1] Plus wettable sulfur 4 lbs. to 100 gals. in both applications.

by jarring an adjacent tree in each of the same plots every third day during this period. The data obtained are given in table 4.

Table 4.—Curculio adults jarred from trees and collected on sheets May 20 to June 11.

Plot No.	Materials Per 100 Gallons[1]	Adults Jarred From Trees 5/20 to 6/11	Adults Found on Sheets 5/20 to 6/11
20	Chlordan (40%) 2.5 lbs.	3	5
17	Air milled benzene hexachloride (6% gamma) 3 lbs.	5	5
15	Impregnated purified gamma benzene hexachloride (5%) 3.6 lbs.	9	11
14	Benzene hexachloride (6% gamma) 4 lbs.	9	4
6	Benzene hexachloride (10% gamma) 1 lb., *Orthex* 1 pt.	12	4
21	Parathion (25%) 1 lb.	13	1
5	Benzene hexachloride (10% gamma) 2 lbs.	16	7
13	Acid lead ars. 2 lbs., hyd. lime 16 lbs.	37	4
9	Acid lead ars. 2 lbs., DDT (50%) 2 lbs. hyd. lime 12 lbs., zinc sulf. 5.5 lbs.	77	2

[1] Applied May 10, May 20 and June 2, plus wettable sulfur 4 lbs. to 100 gals. in each case.

The spray programs involved in this experiment are listed in table 4 in the seeming order of their efficiency in reducing adult curculio populations as indicated by the data obtained by jarring. Considered by themselves, these nine programs ranked as follows, respectively, in order of efficiency in reducing the number of curculio-wormy drops per tree (Table 1): 7-2-4-1-5-6-3-9-8. Excepting the results given by programs 20 and 5, there appears to be a fair degree of positive correlation between the order of efficiency of these programs in reducing adult populations and their order of efficiency in reducing the number of wormy dropped peaches per tree. It will be noted that the differences in the jarring records for the various spray programs involved are not satisfactorily accounted for by corresponding differences in the numbers of affected adults collected on the cheese-cloth sheets. This discrepancy suggests that benzene hexachloride, parathion and chlordan are more repellent to adult plum curculios than acid lead arsenate, as used, and possibly contributed more to control in this way than by killing the adults.

In a second experiment designed to yield information on how the various new insecticides affect plum curculio control under field conditions, a large bouquet of peach twigs with the small peaches attached (obtained from a very lightly infested orchard) were caged with a number of curculio adults for a period of one week. The bouquet was then divided into four equal parts. Three of these were placed in trees in the orchard and the trees then sprayed in a normal manner. After the spray had dried, these parts of the original bouquet and the forth part, which was left unsprayed, were placed in an outdoor insectary for one week. At the end of this time the small green peaches were carefully dissected and the number wormy noted. The results are set forth in table 5.

Table 5.—Effect of benzene hexachloride, parathion and chlordan on immature stages of the plum curculio in green peaches.

Spray Treatments (Materials Per 100 Gallons)	Number of Peaches		% Wormy Peaches
	Total	Wormy	
Air Milled Benzene Hexachloride (6% gamma) 3 lbs.	67	0	0.0
Paration (25%) 1 lb.	55	1	1.8
Chlordan (40%) 2.5 lbs.	63	10	15.9
Check (unsprayed)	76	35	46.1

The results obtained with benzene hexachloride in this test duplicate those obtained with it in a similar test made by the writers in 1947 (Driggers & Darley, 1948). The data show that parathion also is highly effective against early immature stages of the plum curculio in green peach fruits, and chlordan moderately so.

Benzene hexachloride, parathion and chlordan sprays were compared for efficiency in killing plum curculio larvae developing in naturally infested peach fruits on the ground (drops) and on the tree in a third special experiment. A block of Triogem trees adjoining the Glassboro spray plots was left unsprayed by the grower owing to an almost complete loss of crop caused by cold weather during bloom. However, in the most elevated corner of this block, about 25 trees set several hundred fruits each. By the end of May the fruits that had developed on these trees were practically 100 per cent infested by plum curculio larvae in various stages of development and approximately three-fourths of the light crop set had already dropped to the ground. On June 2, 16 of these trees that had set fruit most heavily were divided into four plots. Three of the 4-tree plots were sprayed, including the dropped fruits beneath them, and one was left as an unsprayed check.

Table 6.—Effects of a single spray application of benzene hexachloride, parathion and chlordan on emergence of plum curculio larvae from previously infested peach fruits.

Spray Treatments (Materials per 100 Gallons)	Total Drops	Larvae Emerged	Per Cent Control[1]	Total Picks	Larvae Emerged	Per Cent Control[1]
Air Milled Benzene Hexachloride (6% gamma) 3 lbs.	1271	205	90.3	100	7	96.0
Chlordan (40%) 2.5 lbs.	1351	1262	31.4	100	68	61.0
Parathion (25%) 1 lb.	1598	1482	31.9	100	102	41.4
Check (unsprayed)	1012	1674	0.0	100	174	0.0

[1] Based on emergence per 100 fruits as compared with emergence per 100 check fruits.

About three times the usual volume of spray was applied in order to wet thoroughly all fruits on the trees and on the ground. The day after the sprays had been applied, and again a week later, all dropped peaches were collected from beneath the sprayed and check trees and held in an outdoor insectary in such a way that larval development could continue and emerging larvae could be counted. Daily observations showed that larvae emerged from June 3 to July 7. Also, a week after the trees had been sprayed (*i.e.*, on June 9), 100 fruits were picked from the four trees in each plot and treated in the same manner as the collected drops. The data obtained are given in table 6.

The data in table 6 show that benzene hexachloride is remarkably effective in killing plum curculio larvae infestingpeach fruits, whether the fruits have dropped or still hang on the trees. At the dosage used, chlordan and parathion were only moderately effective in the same use. These results, and those obtained in the previously discussed tests in which bouquets bearing small green peaches were sprayed, indicate that benzene hexachloride, but particularly chlordan and parathion, are more effective in killing curculio larvae in peach fruits the sooner they are applied after larval development begins.

Flavor Comparisons with Harvested Fruit.—At harvest, samples of peaches were taken from various plots in the southern, central and northern New Jersey field experiments and turned over to Dr. W. A. Maclinn, Food Technology Department, New Jersey Agricultural Experiment Station, and Dr. C. C. Mahoney, Raw Products Research Bureau, National Canners Association, Washington, D. C., for flavor comparisons. This work is still in progress and the results will be reported as soon as available.

Summary.—Spray tests were made in southern, central and northern New Jersey peach orchards in 1948. In programs of two to five applications made at 10-day intervals, various benzene hexachloride spray powders at dosages providing the gamma isomer at 0.09 to 0.24 lb. per 100 gallons gave equal to appreciably better control of plum curculio (as measured by number of curculio-wormy dropped peaches per tree) than parathion at 0.25 lb. per 100 gallons, much better control than chlordan at 1 lb. per 100 gallons, and very much better control than acid lead arsenate at 2 lbs. per 100 gallons.

In the southern New Jersey tests, evidence was obtained that the efficiency of benzene hexachloride spray powders in reducing plum curculio reproduction on peaches is increased by increasing the dosage of gamma isomer, making more frequent or more numerous applications, reducing the particle size of the powder, or by use of suitable spray coverage supplements. No differences in the results obtained with the various benzene hexachloride spray powders tested can be attributed to differences in brand or in percentage or degree of refinement of their gamma isomer content.

A number of special tests were made in southern New Jersey to obtain information on how these new insecticides affect plum curculio control on peaches under field conditions. Evidence was obtained that the spray deposits given by benzene hexachloride, parathion and chlordan spray powders in the programs used are more repellent to adult plum curculios than the spray deposits given by acid lead arsenate with or without DDT, and that these organic insecticides possibly contribute more to plum curculio control in this way than by killing the adult curculios. At a dosage providing 0.18 lb. of gamma isomer per 100 gallons, benzene hexachloride was very effective in killing

plum curculio larvae infesting peach fruits, whether the infested fruits were sprayed on the tree or after having dropped to the ground. Parathion and chlordan were considerably less effective in this respect at 0.25 lb. and 1 lb. per 100 gallons, respectively. Evidence was also obtained that benzene hexachloride, but especially parathion and chlordan, are more effective in killing plum curculio larvae in peach fruits the sooner they are applied after larval development begins.

Flavor comparisons of harvested fruit from various plots are still in progress.

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Tests of Insecticides for Control of Cat-Facing on Peaches

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The scarring and distortion of peaches which results from the attacks of sucking insects when the fruits are small has been the cause of considerable losses to Virginia peach growers. Most such injury has been caused by the tarnished plant bug and by stinkbugs of the genus *Euschistus*, which remain on the peach trees a relatively short time in the spring. Tarnished plant bugs come to the peach trees when they are in bloom, or even earlier, and most of them leave the peach soon after the petals drop. The stinkbugs, on the other hand, seldom become common on peaches until the shucks are splitting, and most of them leave the trees by the first of June, although a few may be found on peach trees considerably later.

In 1946 work was started with the testing of the effectiveness of some of the newer insecticides in reducing the injury caused by these bugs on peach. Experiments were conducted during one or more seasons in each of the following peach orchards: the J. T. Henley orchard near Crozet, the orchard of McCue & Son at Greenwood, the Fox Hill orchard of the Union Apple Company near Staunton, and the Alexander orchard near Fairfield. Each of these orchards had a record of heavy losses in recent years as a result of scarring, or cat-facing of the fruit.

The experimental plots in the Henley orchard were located at the top of a ridge where the orchard adjoins a woodland. Weeds usually grew rankly along the strip of ground between the peach trees and the fence at the edge of the woods, and in open spaces in the woods. There were also some outcrops of rock in the orchard, around which there was usually a heavy growth of weeds. Bermuda grass and weeds formed the cover crop in this part of the orchard, which was not cultivated except in the spring. Practically all of the fruits in the immediate area of the orchard where the plots were located were scarred as a result of the feeding of the tarnished plant bug in 1944 and 1945. The results of the jarring of trees along the border of the orchard showed that the

infestation of tarnished plant bug was particularly heavy in 1944, 1945, and 1946, and that there were also some stinkbugs on the trees. The infestation of tarnished plant bug was much lighter in 1947 than it had been during the previous three seasons.

The experiments in the McCue orchard were located in a block of peach trees bordered by woods and by apple orchard in sod. A strip of land along the edge of the woods had been cleared, and this usually supported a heavy growth of weeds. Rye was used as a cover crop during the winter, and the orchard was cultivated several times in the spring. In 1946 there was a heavy infestation of the stinkbug *Euschistus servus* (Say), and of the tarnished plant bug, in the peach trees along the edge of the woods.

The peaches at the Fox Hill orchard are bordered by pasture, hay fields, and apple orchard in sod. They had not been cultivated regularly for several years, and there was a heavy growth of weeds and grass among the trees at the time the experimental work was carried on. The loss due to cat-facing of fruits had been heavy for several years prior to 1946, and there had been a heavy infestation of a stinkbug, *Euschistus tristigmus* (Say), each season that trees had been jarred. This infestation was lower in 1948 than it had been for several years.

The peaches in the Alexander orchard are bounded by pasture and crop land. The peach orchard was not cultivated in 1947 or 1948, but the growth of weeds was not heavy. There was much scarred fruit in 1947, but no collections were made to determine what insects were responsible for this injury.

METHODS AND MATERIALS.—Various insecticides were tested against the bugs which cause cat-facing of peaches by applying them, as sprays or dusts, to small plots in these orchards. The dusts were applied with a rotary hand duster, and the sprays with a power orchard sprayer. The plots used varied in size from 4 to 12 trees, and each treatment was replicated three times. Dusts were tested only in 1946. The following materials were tested as sprays during one or more seasons at the indicated rate per 100 gallons: 2 pounds of 50 per cent DDT, 4 pounds of 50 per cent activated sabadilla, 3 pounds of 50 per cent (6 per cent gamma isomer) benzene hexachloride (the benzene hexachloride used in 1946 contained 3.9 per cent gamma isomer and 31.6 per cent total isomers), 2.5 pounds of 40 per cent chlordan, and 4 pounds of 25 per cent chlorinated camphene. The dusts tested in 1946 contained the following percentages of toxicants: DDT, 5 per cent; activated sabadilla, 10 per cent; and benzene hexachloride, 3.2 per cent (0.39 per cent gamma isomer).

In 1946 DDT, activated sabadilla, and benzene hexachloride were tested in experiments in the Henley, McCue, and Fox Hill orchards. Each of these materials was applied as a spray in the Henley orchard; each was applied both as a spray and as a dust in the McCue orchard; and each was applied both as a spray and as a dust in the Fox Hill orchard, with the omission of DDT dust. The schedule of treatments in each orchard began with the petal-fall application. Three treatments were applied in the Henley and Fox Hill orchards, and four were applied in the McCue orchard.

Since the results of the 1946 tests indicated that considerable injury might be taking place before the application of the petal-fall spray, a full-bloom spray was added to the schedule in the 1947 tests. Experiments were conducted in the Henley and the McCue orchards. The materials tested were DDT, activated sabadilla, and benzene hexachloride. The plots, each containing about 25 peach trees, were laid out in three replicates. Each large plot was divided into three sub-plots. One sub-plot in each large plot was sprayed when the trees were in full bloom, a second was sprayed at full bloom

Table 1.—Results of treatments applied to peach trees for the control of insects causing cat-facing, 1946.

INSECTICIDE	HOW APPLIED[1]	FRUITS SCARRED	
		McCue Orchard	Fox Hill Orchard
		Per cent	*Per cent*
DDT	Spray	9.0	7.2
DDT	Dust	16.7	
Sabadilla	Spray	11.3	2.2
Sabadilla	Dust	16.7	7.2
Benzene hexachloride	Spray	11.3	4.0
Benzene hexachloride	Dust	21.0	12.0
Check		25.5	27.2

[1] Four treatments were applied in the McCue orchard and three in the Fox Hill orchard. The schedule of treatments in each orchard started with the petal fall application.

Table 2.—Results of sprays applied to peach trees for the control of insects causing cat-facing, 1947.

Insecticide	Sprays Applied	Fruits Scarred	
		Henley Orchard	McCue Orchard
		Per cent	*Per cent*
DDT	Full bloom	6.3	3.7
DDT	Full bloom and petal fall	2.7	2.7
DDT	Petal fall	4.7	3.3
Sabadilla	Full bloom	4.7	4.0
Sabadilla	Full bloom and petal fall	3.7	2.3
Sabadilla	Petal fall	4.3	5.3
Benzene hexachloride	Full bloom		5.0
Benzene hexachloride	Full bloom and petal fall	7.3	3.7
Benzene hexachloride	Petal fall		5.1
Check	None	1.53	13.2

Table 3.—Results of sprays applied to peach trees for the control of insects causing cat-facing, 1948.

Insecticide	Sprays Applied	Fruits Scarred	
		Fox Hill Orchard	Alexander Orchard
		Per cent	*Per cent*
DDT	Full bloom	6.1	
DDT	Full bloom and petal fall	5.5	
DDT	Petal fall	5.0	3.0
Benzene hexachloride	Full bloom	12.2	
Benzene hexachloride	Full bloom and petal fall	11.0	
Benzene hexachloride	Petal fall	11.3	5.7
Chlordan	Full bloom	10.5	
Chlordan	Full bloom and petal fall	10.3	
Chlordan	Petal fall	10.4	5.7
Chlorinated camphene	Petal fall		5.0
Check	None	15.1	8.2

and petal fall, and the third was sprayed at petal fall only. A second experiment was laid out in the same way and the respective sub-plots were sprayed with the same materials at the shuck-split stage, at the shuck-split stage and one week later, and one week after the shuck-split stage.

Experiments were conducted in the Fox Hill orchard and the Alexander orchard in 1948. At the Fox Hill orchard the plots were divided as had been done in 1947, and the sub-plots were sprayed at full bloom, at full bloom and petal fall, and at petal fall. Each treatment was replicated four times in this orchard. In the Alexander orchard only a petal-fall spray was applied. DDT, benzene hexachloride, and chlordan were used in the Fox Hill orchard; these materials and chlorinated camphene were used in the Alexander orchard.

The results of these spray and dust treatments were evaluated by taking a sample of fruits from the trees of each plot in June just before the peaches were thinned. The fruits of each sample were examined for scars caused by the feeding of insects, and the number of scarred fruits was noted.

RESULTS.—In 1946 the experimental block in the Henley orchard was so heavily infested by the tarnished plant bug that practically 100 per cent of the fruits on both the sprayed trees and the unsprayed trees were scarred as a result of their feeding. No comparison of the effects of the different insecticides was possible. This experiment did show, however, that much of the scarring might take place before the petal-fall spray.

The results of the experiments in the McCue and Fox Hill orchards in 1946 are shown in table 1. The dusts were less effective than the sprays. The respective treatments were more effective in reducing injury in the Fox Hill orchard at Staunton than in the McCue orchard at Greenwood. This may have been due to the fact that the infestation of tarnished plant bug was much higher in the McCue orchard than in the Fox Hill orchard, while the infestation of stinkbugs was higher in the Fox Hill orchard. It is probable that some of the injury in the former orchard was the result of feeding done by the plant bugs before the petal-fall treatments were applied; whereas in the latter orchard the stinkbugs came to the peach trees after the beginning of the spray schedule, thus making it more effective in their control.

The results of the 1947 experiments are shown in table 2, and those of 1948 in table 3. These figures require little comment, but it will be noted that the petal-fall spray was very slightly more effective than the full-bloom spray, and that the two sprays together were only slightly better than one. The sprays applied at the shuck-split stage and a week later in 1947 were ineffective, and the results of this experiment are not included in the table.

SUMMARY.—Sprays were more effective than dusts in reducing cat-facing of

peaches. Experiments showed that DDT, at the rate of 2 pounds of 50 per cent wettable powder per 100 gallons, applied either at full bloom or at petal fall, gave a satisfactory control of the insects that cause cat-facing. Sabadilla, at the rate of 4 pounds of 50 per cent powder per 100 gallons, was about as effective as DDT. Benzene hexachloride, chlordan, and chlorinated camphene were less effective. There was little difference in the value of the full-bloom and the petal-fall spray, and two sprays gave only slightly better results than one. In some seasons the petal-fall spray may be too late to prevent damage by the tarnished plant bug as this insect sometimes causes damage before the petals drop.

Control of Pear Psylla in the Pacific Northwest

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After the pear psylla, *Psylla pyricola* Foerst., was discovered near Spokane, Washington, in 1939, the Bureau of Entomology and Plant Quarantine started a control program that was intended to eradicate this insect from the Pacific Northwest if possible, or at least to prevent it from spreading to commercial pear-growing areas. Later surveys revealed the response of the psylla in the Wenatchee and Yakima Valleys, where there are almost 2 million pear trees, and also in British Columbia. Because of this large area of infestation, the Bureau's control program was discontinued at the end of 1947. This meant that the growers would have to contend with this pest and would need materials that would be available and dependable.

Since the use of oil as a dormant spray could not be depended on to control the psylla for the entire season, and since nicotine sulfate, which has been a standard summer spray, would probably not be available in sufficient quantity to protect the 10 million pear trees on the Pacific Coast should they become infested, other means of control were needed. The Bureau had already started work on this problem in New York (Hamilton 1947, 1948), and research was conducted in the Pacific Northwest in 1947 and 1948 to determine the best means of control for the West. The work was done in British Columbia in 1947, in cooperation with the Canadian Department of Agriculture, and in Chelan County, Washington, in 1948, in cooperation with the State College of Washington and the Washington State Department of Agriculture.

In the two seasons more than 20 materials were tested, some of them only in a preliminary way and others rather thoroughly. For each test 1 to 40 trees were sprayed with a power sprayer at a pressure of about 500 pounds per square inch. The nymphs on 10 or 12 spurs from 1 to 4 trees were counted immediately before spraying, a day or two afterwards, and at intervals thereafter to determine the residual value of the materials. This paper gives the results of the tests, together with information on the effect of dormant sprays and the injury caused by some of the test materials. The results of the more important tests are shown in figures 1 to 4.

LARGE-SCALE TESTS.—Figure 1 gives the results of tests made in 1947 in a Bartlett pear orchard which was shown by preliminary counts to have an infestation of 20 to 30 nymphs per spur. Nymphs were not counted in all plots before treatment, but several trees were left unsprayed for later comparison with the sprayed trees. Tetraethyl pyrophosphate[2] applied at 0.5 pint[3] was initially very effective, the population being practically zero shortly after spraying, but the nymphs increased rapidly after treatment. Benzene hexachloride containing 6 per cent of the gamma isomer when used at 1.5 pounds greatly reduced the population, which increased thereafter rather slowly. One pound of a product containing 1 per cent of rotenone not only greatly reduced the infestation but prevented it from increasing for 2 months. Nicotine sulfate, at 0.75 pint of a 40 per cent material with 2

[1] The authors were assisted in this work in 1947 by J. I. Mason, Geo. H. Kaloostian, Norton S. Wilson, and William Holland.

[2] Active ingredients, according to manufacturer: tetraethyl phosphate 9 per cent, other organic phosphates 16 per cent.

[3] All quantities mentioned in this paper are for 100 gallons of spray.

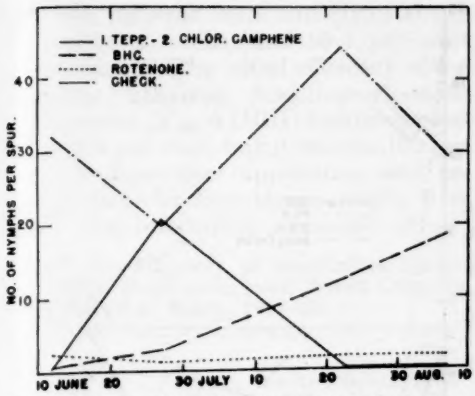

FIG. 1.—Pear psylla infestation in plots in Bartlett orchard sprayed with various insecticides, on July 7, 1947, British Columbia. TEPP = tetraethyl pyrophosphate; Chlor. camphene = toxaphene; BHC = benzene hexachloride.

quarts of mineral oil (not shown in the figure), gave almost as good results as the rotenone. Because the infestation in the trees sprayed with tetraethyl pyrophosphate had risen to more than 20 nymphs per spur by June 28, these trees were sprayed on July 2 with 1.5 pints of a 50 per cent emulsible chlorinated camphene. This spray reduced the population to almost nothing, where it remained for more than a month.

It was concluded from these tests and others made in 1947 that the major tests in 1948 should include benzene hexachloride, chlorinated camphene, nicotine sulfate, parathion, and rotenone. These materials were therefore used in various dilutions in plots of 15 to 40 trees each in three d'Anjou orchards in the Entiat Valley, Chelan County, Washington. In two of these orchards a heavy overwintering population of psyllas had been reduced to a very low point by dormant sprays of 3.2 per cent mineral oil that had been put on by the owners early in April. The population remained low until late in June, when it began to increase, and summer sprays were applied on July 8. The results in these two orchards were very similar; hence only the results of representative tests from one of them are shown (Fig. 2).

Chlorinated camphene (50 per cent) at 1 pint had an initial efficiency[1] of 95 to 100 per cent, and kept the infestation below one nymph per spur for 6 weeks, after which it began to rise. Where 1.5 pints was used (not shown in the figure), the infestation remained below one nymph per spur in both orchards for more than two months. Parathion (25 per cent) at 2.5, 5, and 10 ounces showed an initial efficiency of 100 per cent and kept the infestations well below one nymph per spur for 8 to 10 weeks. Benzene hexachloride containing 12 per cent of the gamma isomer, however, when used at the rate of 1 pound with 2 quarts of mineral oil, allowed the infestations to rise rapidly in both orchards after about 6 weeks, although the initial efficiency was 90 to 100 per cent. The standard application of 0.75 pint of 40 per cent nicotine sulfate with 2 quarts of mineral oil kept the infestation very low for 6 weeks, after which it rose slowly. Rotenone, at 1 pound of 1 per cent material with 2 quarts of mineral oil (not shown in the figure), gave results similar to those obtained with nicotine sulfate and oil.

[1] Figured by dividing the number of psylla nymphs before spraying or in a check into the difference between that figure and the infestation after spraying.

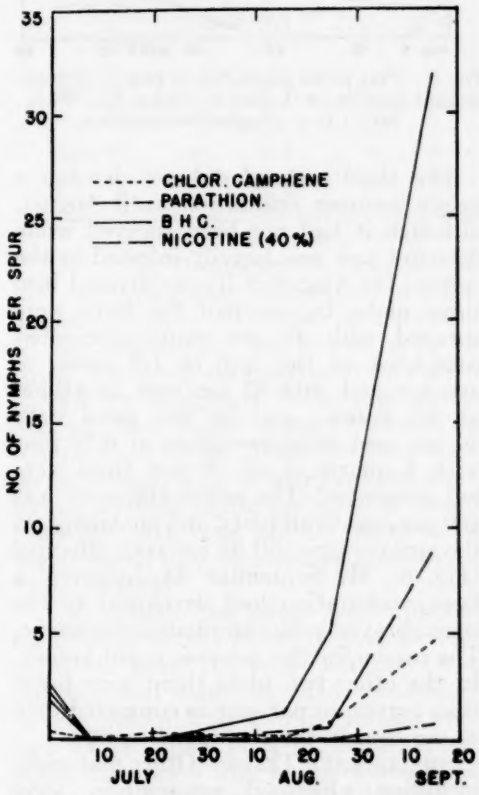

FIG. 2.—Pear psylla infestation in plots in d'Anjou orchard sprayed on July 8, Chelan Co., Wash., 1948. Chlor. Camphene = toxaphene; BHC = benzene hexachloride.

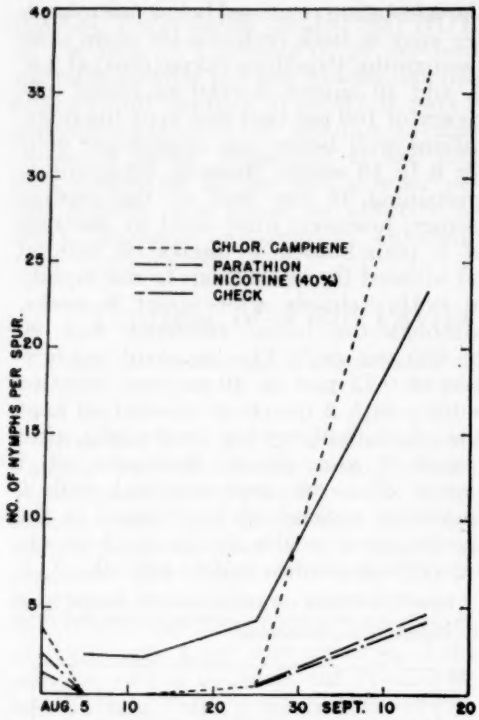

FIG. 3.—Pear psylla infestation in plots in d'Anjou orchard sprayed on August 3, Chelan Co., Wash., 1948. Chlor. camphene = toxaphene.

The third orchard did not develop a heavy summer infestation until August, although it had not been sprayed while dormant and was heavily infested in the spring. On August 3 it was divided into three plots. In one plot the trees were sprayed with 42 per cent chlorinated camphene at the rate of 1.2 pints, in another plot with 25 per cent parathion at 2.5 ounces, and in the third with 40 per cent nicotine sulfate at 0.75 pint with 2 quarts of oil. A few trees were left unsprayed. The initial efficiency was 100 per cent in all plots, and on August 25 the sprays were still 98 per cent effective (Fig. 3). By September 24, however, a heavy infestation had developed in the trees sprayed with chlorinated camphene. The reason for this increase is not known. In the other two plots there were fewer than 5 nymphs per spur as compared with 23 per spur in the unsprayed trees.

SMALL-SCALE TESTS.—Other materials, including piperonyl compounds, were used in 1947 and 1948 on small plots of one to three trees, and spurs were examined from each tree. The results are

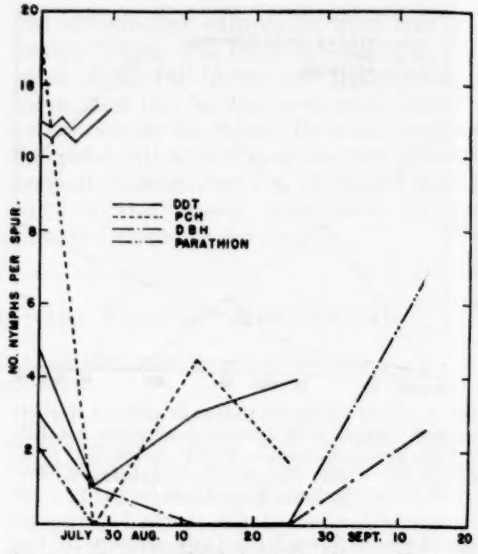

FIG. 4.—Pear psylla infestation in small tests, Chelan Co., Wash., 1948. PCH = piperonyl cyclonene; DBH = disodium ethylene bisdithiocarbamate hexahydrate.

given in table 1, in terms of the percentage of efficiency, and the number of nymphs per spur is given in figure 4. The mineral oil was the same as that used with nicotine sulfate and other insecticides; it had a viscosity of 62 seconds (Saybolt) and an unsulfonated residue of 79 per cent.

The purpose of the tests with piperonyl compounds, alone or with pyrethrins, was to find out whether they would improve the control obtained with rotenone. Brannon (1947) had shown that these compounds have a synergistic effect when used with rotenone against the Mexican bean beetle, and it was thought that there might be a similar effect against the pear psylla. When these compounds were used at 1 or 2 pints, the initial efficiency was always 95 per cent or higher, but within 2 weeks it had dropped below 90 per cent. The results obtained on a representative plot are shown in figure 4 (PCH). A month after spraying the efficiency was still about 80 to 90 per cent (Table 1). However, rotenone alone gave at least as good results, the efficiency being 90 to 100 per cent initially, 85 to 95 per cent at the end of 2 weeks, and 80 to 93 per cent at the end of a month. These results show that there is no advantage in using the piperonyl compounds with rotenone. The efficiency of 5 ounces of 25 per cent parathion in a comparable

test was 99.5 per cent initially, 100 per cent after 2 weeks, and 99.5 per cent after a month. The initial efficiency of the disodium ethylene bisdithiocarbamate hexahydrate (Fig. 4 DBH) treatment was only 70.6 per cent, but it rose to 100 per cent 16 days after application and remained there for more than a month, after which the infestation increased slowly.

Table 1.—Efficiency of insecticides against pear psylla. Small-scale tests, British Columbia and Chelan Co., Wash., 1947–48.

Material	Quantity per 100 Gal.	Initial Efficiency	Efficiency After 30 Days
		Per Cent	*Per Cent*
Chlordan (50% emulsion concentrate)	0.5 pt.	47.7	60[1]
	1 pt.	57.9	60[1]
Chlordan (about 100%)	1 lb.	61.5	—
	1.5 lb.	69.3	—
DDT (50% wettable powder)	2 lb.	38.9	0
	4 lb.	77.1	18.8
1,1-bis(*p*-chlorophenyl) ethanol, 25%	1 pt.	29.4	0
	2 pt.	64.7	0
Bis(*p*-chlorophenoxy)methane, 40%	1 lb.	34.8	0
	2 lb.	75	0
Disodium ethylene bisdithiocarbamate hexahydrate, 25%	2 qt.	70.6	100
Lorol-2-thiazolinyl sulfide	1 pt.	64	0
	2 pt.	75	0
Mineral oil	2 qt.	55	—
Rotenone 1 gram plus:[2]			
Piperonyl cyclonene 1 gram	1 pt.	98.6	83.8
	2 pt.	99.4	86.1
Piperonyl cyclonene 2 grams plus pyrethrins 0.2 gram	1 pt.	98.3	85.3
	2 pt.	100	91.1
Piperonyl butoxide 4 grams	1 pt.	98.7	83.9
	2 pt.	99.3	91
Piperonyl butoxide 2 grams plus pyrethrins 0.2 gram	1 pt.	97.5	80.8
	2 pt.	99.7	90
Rotenone, 1.5%	0.67 pt.	90.5	80.2
	1.33 pt.	100	93.3
Parathion, 25%	5 oz.	99.5	99.5

[1] Estimated.
[2] Quantities per 100 ml.

Some of the materials used in these small-scale tests might be more effective if used in greater quantities, but present costs would make such use impracticable.

INJURY CAUSED BY SPRAYS.—No pear fruit or foliage was injured by any of the five most promising materials—namely, chlorinated camphene, parathion, rotenone, nicotine sulfate, and benzene hexachloride. Cooperative tests in Oregon[1] showed that chlorinated camphene, parathion, and benzene hexachloride did not injure d'Anjou, Bartlett, Bosc, Comice, and Winter Nelis pears except that the chlorinated camphene produced russeted rings where the drops of spray dried on the fruit of Comice. The chlorinated camphene burned the leaves when applied with or just following an application of mineral oil. There was some foliage injury and slight fruit injury on Bartletts sprayed with tetraethyl pyrophosphate, and more serious injury, in the form of russeted rings where the drops of spray dried on the pears, from the use of one of the piperonyl compounds in 1947. Shortly before harvest yellow spots appeared on the skin of Bartletts sprayed with Lorol-2-thiazolinyl sulfide. The other materials caused no injury.

Table 2.—Comparison of numbers of nymphs per spur in orchards receiving dormant mineral oil sprays and in unsprayed orchards.

Date of Count	Sprayed Orchards		Unsprayed Orchards	
	No. 1	No. 2	No. 3	No. 4
April 14	0	0	—	—
21	0.3	0.1	—	—
26	1	2	3.1	4.1
May 4	.7	1.3	6.2	5.1
12	1	1	—	9.1
June 21	2	1.1	—	—
July 6	—	1.6	—	—

EFFECT OF DORMANT OIL SPRAYS.—In two orchards under observation in 1948, a dormant spray of 3.2 per cent mineral oil was applied by the owners early in April. This is the standard dilution used in the Pacific Northwest. A few pear psylla eggs had been found in these orchards on March 24, and by March 31 there were on an average three or four eggs and more than one adult psylla per spur. It would probably have been better, therefore, if the orchards had been sprayed a week or 10 days earlier.

A week after the sprays were applied, many dead adults could be found clinging to the spurs and twigs, and there was evidence that many eggs had been killed. In one orchard only two live adults were seen on 140 spurs, and in the other orchard there were only nine live adults on 300 spurs. Adults were still plentiful in

[1] Made by L. G. Gentner, Southern Oregon Branch Experiment Station, and Leroy Childs, Hood River Branch Experiment Station.

near by unsprayed orchards. The nymphs per spur were counted for a time in these orchards as well as in two unsprayed orchards. Table 2 shows that the number increased in the unsprayed orchards but remained low in the sprayed orchards until late in June.

DISCUSSION.—Parathion, chlorinated camphene, and rotenone, materials which were more effective than nicotine sulfate in controlling the pear psylla, are also effective for controlling mites. This is an important discovery since most pear growers use DDT to control the codling moth and a heavy infestation of mites may result.

Parathion is a very poisonous material and should be handled with great care. Until more is known about the danger of small amounts of this material on fruit at harvest its use is not recommended. If it is used experimentally, a month or more should be allowed between the last application and harvest. Likewise, little is known concerning the persistence of chlorinated camphene residues on fruit or the danger of residues of this material that may be present on the fruit at harvest. Recommendations cannot be made for its use until such information is available.

SUMMARY.—Of the materials tested on a large scale in 1947 and 1948 for controlling the pear psylla, *Psylla pyricola* Foerst., four were very effective as foliage sprays. They are parathion, chlorinated camphene, rotenone, and nicotine sulfate. The last two were used with mineral oil. Benzene hexachloride was also very effective initially, but it had less residual value than the others. Disodium ethylene bisdithiocarbamate hexahydrate, a material tested only on a small scale, also showed much promise and warrants further trial.

These materials were generally safe when applied to pear fruit and foliage. Exceptions were that chlorinated camphene produced russeted rings where drops of spray dried on the fruit of Comice pears in Oregon and burned pear leaves when applied with or just following an application of mineral oil. Benzene hexachloride also imparts an off or musty flavor to fruit to which it is applied too close to harvest.

A dormant spray of mineral oil is also effective against the pear psylla and its use may make unnecessary any further spraying for the psylla until early in July.

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DR. VORHIES DIES IN WASHINGTON

Dr. Charles T. Vorhies, Vice President of the National Wildlife Federation, Tucson, Arizona, was stricken in Washington, D. C., early Saturday morning March 5, 1949, at the Statler Hotel with a heart attack and died at the Doctors Hospital about seven o'clock on the evening of March 10. He was 69 years of age. He had been Professor of Zoology at the University of Arizona for many years and was always an enthusiastic conservationist. Dr. Vorhies was Chairman of the National Wildlife Federation's Committee on Conservation Education and had just completed editing a new publication for the Federation before coming to Washington to attend the Conference. He was Secretary of the Arizona Wildlife Federation. He is survived by his widow and an only son. Funeral services were held in Tucson. His splendid counsel will be missed by all who knew him throughout the Nation.

Sprays for Control of the Peach Tree Borer

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The peach tree borer, *Sanninoidea exitiosa* (Say), is the most injurious insect pest of peach trees in Virginia and has been the most difficult to control. Treatments with paradichlorobenzene crystals and liquid, and emulsions of ethylene dichloride have given satisfactory control of borers in the tree trunks when properly applied. Peach tree borer populations, however, have been perpetuated by moths developing from larvae in roots from 12 to 36 inches out from the base of the trees. Furthermore, it is sometimes difficult to treat the trees at the proper time and in some cases injury has resulted. Driggers & Smith (1944) indicated reductions in borer populations in trees sprayed with DDT to control the oriental fruit moth and stimulated work with trunk sprays for peach borer control. LaPlante & Wheeler (1948) obtained effective control of the peach borer with DDT at concentrations of one or more pounds of toxicant per 100 gallons, sprayed directly on trunks, crotches, and limb bases. They state that applications must begin with the first hatch and be repeated at 3-week intervals until the latter part of August.

This is a report of results obtained in tests with DDT, chlordan, and parathion during 1947 and 1948.

Field Experiments, 1947.—The tests were conducted in a 10-acre block of peach trees of the Elberta variety. Each treatment was replicated twice on five-tree plots, and the plots were separated by four rows of untreated trees. Each concentration of the insecticide was used on 30 trees and three treatments were made. Ten trees were sprayed once (July 8), 10 trees twice (July 8 and August 12), and 10 trees three times (July 8, July 29, and August 12). Check trees consisted of 10 trees on the east side and 10 trees on the west side of the treated block, four rows away from the last treated plot, and 10 trees in the center of the experimental block which was separated by one row from the sprayed trees.

Treatments were made with a compressed-air sprayer at about 50 pounds of pressure and 1 pint of liquid was applied per tree to the trunk and crotch.

The fall was unusually warm in 1947 and egg hatching and borer activity did not cease until October 15. Thus, an opportunity was afforded for a study of the residual effectiveness of the insecticides. It will be noted in table 1 that larvae increased in numbers throughout September and early October in the check trees and in trees sprayed with some of the less effective spray concentrations. DDT at the rate of 2 or 4 pounds per 100 gallons of water in two or three applications, the last on August 12, was still effective in killing larvae 9 weeks after application. A 1 per cent liquid formulation of DDT still showed residual killing after 14 weeks. Chlordan did not possess the residual effectiveness of DDT and did not give satisfactory control.

Field Experiments, 1948.—Experiments during 1948 were conducted in two peach orchards of the Elberta variety. Orchard A consisted of large vigorous trees and had a relatively low initial borer infestation. Each treatment was replicated twice on five-tree plots. There were no buffer rows between the plots, but the check trees were located around the outside of the treated block. Two applications of the insecticide were made on some plots, July 9 and August 19, and three to other plots, July 9, August 9, and September 9. In one treatment, only one trunk spray was made, July 19, but this was preceded by two applications of DDT for oriental fruit moth control, on June 24 and July 15, at the rate of 1 pound of actual DDT per 100 gallons of spray.

Orchard B consisted of less vigorous trees. No borer treatments had been applied during the previous 2 years and there was a high borer infestation in the orchard. Each treatment consisted of four two-tree randomized plots. The checks were also at random in the replicated plots.

The data in table 2 indicate that all DDT treatments in orchard "A" of two or three applications gave satisfactory control, 95 per cent or more, but one application of 4 pounds of actual DDT following two sprays for oriental fruit moth control gave only 87.78 per cent control of the

Table 1.—Results obtained in 1947 with DDT and chlordan in trunk sprays to control the peach tree borer.

Materials per 100 Gallons[1]	Number Applications[2]	Average Number Borers per Tree on—			Per Cent Control on—		
		Sept. 9	Sept. 29	Oct. 24	Sept. 9	Sept. 29	Oct. 24
DDT,[3] 2 pounds	1	2.22	3.22	4.56	52.77	46.95	39.67
	2	0.56	0.56	0.89	88.08	90.77	88.23
	3	0.33	0.33	0.33	92.98	94.56	95.59
DDT,[3] 4 pounds	1	2.12	3.00	3.88	54.89	50.58	48.68
	2	0.11	0.33	0.67	97.66	94.56	91.17
	3	0.10	0.00	0.00	97.87	100.00	100.00
DDT,[4] 1%	1	0.33	0.89	0.89	92.98	85.34	88.23
	2	0.10	0.00	0.00	97.87	100.00	100.00
	3	0.00	0.00	0.00	100.00	100.00	100.00
Chlordan, 1 pound	1	3.50	3.70	6.30	27.66	39.04	16.56
	2	0.75	1.50	2.38	84.04	75.29	68.54
	3	0.00	1.33	2.17	100.00	78.09	71.17
(west side)		4.80	6.25	7.80			
Check (within plots)		3.89	4.68	5.67	17.23	22.90	24.94
(east side)		4.60	5.90	7.30			

[1] Actual amounts.
[2] Date for 1 application July 8, 2 applications July 8 and August 12, 3 applications July 8, July 29, and August 12.
[3] Wettable powder.
[4] Liquid formulation in oil base.

Table 2.—Results obtained in 1948 with DDT, chlordan, and parathion in trunk sprays to control the peach tree borer.

Materials per 100 Gallons[1]	Number Applications[2]	Orchard A		Orchard B		
		Average Number Borers per Tree	Per Cent Control	Average Number Borers per Tree	Per Cent Control[3]	Per Cent Control[4]
DDT,[6] 2 pounds	2	0.11	95.93	2.75	8.33	70.53
	3	0.10	96.30	1.75	41.67	81.24
DDT,[6] 4 pounds	1[5]	0.33	87.78	0.50	83.33	94.64
	2	0.00	100.00	0.13	95.67	98.61
	3	0.00	100.00	0.00	100.00	100.00
DDT,[7] 0.5%	2	0.10	96.30	0.13	95.67	98.61
	3	0.00	100.00	0.00	100.00	100.00
DDT,[7] 1%	2	0.00	100.00	0.00	100.00	100.00
	3	0.00	100.00	0.00	100.00	100.00
Chlordan, 1 pound	2	0.20	91.48	2.50	16.67	73.20
	3	0.20	91.48			
Parathion, 4 ounces	2	0.00	100.00	0.38	87.33	95.93
	3	0.00	100.00			
Check (outside plots)		2.70		3.00		67.85
				9.33		

[1] Actual amounts.
[2] Date for 1 application August 19, for 2 applications July 9 and August 19, and for 3 applications July 9, August 9, and December 9.
[3] Based on randomized check trees within test area.
[4] Based on check trees outside of test area.
[5] Two sprays for oriental fruit moth control applied in orchard A on June 24 and July 15 in addition to trunk spray.
[6] Wettable powder.
[7] Liquid formulation in oil base.

borers. Chlordan was less effective at the dosage used than DDT, but parathion gave 100 per cent kill of the borers.

In orchard "B" the borer population was much greater than in orchard "A," although the randomized check plots did not show this difference. Effective control was obtained with the 0.5 and 1 per cent liquid formulations of DDT and with 8 pounds of 50 per cent wettable DDT to 100 gallons of water. One application of 4 pounds of actual DDT to 100 gallons made at the peak of moth activity, August 19, gave good control of borers. It must be pointed out that notes made at the time of application showed from two to eight larvae per tree and the 4-pound dosage killed the majority of these larvae even though they were established in the bark before the insecticide application was made.

DISCUSSION.—Peachtree borer moths begin emerging in late June and continue to emerge until late September, with the peak of emergence occurring about mid-August. DDT applications to tree trunks kill moths visiting the sprayed tree as well as larvae, and this method of peach tree borer control has given excellent experimental and commercial control in Virginia. It is easy to apply, no borer injury is caused to the trees during the summer, as is the case with other methods, and it is non-injurious to all ages of trees.

One application of 4 pounds of actual DDT per 100 gallons of water, made at the peak of moth activity, was more effective than three applications of 2 pounds each (Table 2). Data obtained up to the present indicate that the minimum amount for effective control with two applications is 4 pounds of actual DDT per 100 gallons of water. Two pounds of DDT have given satisfactory control in orchards with light borer infestations but can not be depended upon in orchards with heavy infestations unless frequent applications are made. Applications proved most effective when the first was made in early July, after the first moths had emerged, and the second in mid-August. These fit into the fruit grower's schedule, since the important second application is made after the completion of the peach harvest and before the apple harvest begins.

The writer observed in 1946 that check trees within randomized treatments did not have as many borers as trees on the outside of the test area. In table 1 it will be noted that check trees within the test area had 24.95 per cent fewer larvae than trees without the experimental area. In 1948 two-tree replicates in randomized plots were used in orchard "B" (Table 2). The randomized check trees within the test area averaged 3.0 larvae per tree while check trees outside of the test area averaged 9.33 larvae per tree, which was a reduction in borer population in check trees within the experimental area of 67.85 per cent.

SUMMARY.—Applications of sprays containing DDT to the trunks and crotches of peach trees have proved effective in controlling the peach tree borer in Virginia. This insecticide kills larvae and adult moths. Results show that two applications, the first in early July and the second in mid-August, containing 4 pounds of actual DDT per 100 gallons of water gave satisfactory control of the borer. This concentration had a residual effectiveness of 9 weeks in 1947 tests.

Chlordan at 1 pound per 100 gallons of water was not as effective as DDT and had a relatively short period of residual killing.

Parathion was used at the rate of 1 pound of 25 per cent material per 100 gallons of water in 1948 and gave excellent control in an orchard with a light infestation and good control in a heavily infested orchard.

DDT trunk sprays have marked advantages over paradichlorobenzene and ethylene dichloride emulsion treatments.

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Codling Moth and Mite Control in 1948[1]

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The codling moth has been extremely difficult to control in Western Colorado. Our experimental tests, the experience of the growers, and the work of Hough (1928, 1929, 1935, 1943) have clearly shown that the Colorado strain is definitely resistant to many controls. The use of DDT is showing phenomenal results. It is too early to say whether the Colorado strain is showing any resistance to this material that is not present in the species in other areas. However, our 1948 research results make us wonder if we are getting as effective control as is reported by many others. Possibly we have had an especially favorable season for the insect. In common with most other workers we are experiencing a definite increase of mites in the DDT sprayed orchards. Our experiments were planned this season with the hope of developing a program effective in the control of the mites as well as of the codling moth. Our most serious mite species are the clover mite, *Bryobia praetiosa* Kock, and the common red spider, *Tetranychus* spp. The former was by far the more numerous and injurious in the test plots. A comparatively small number of mites of this species can cause serious injury.

Methods and Materials.—All tests were made in a Jonathan orchard belonging to Thomas Bird, Paonia. Single tree randomized plots were used. Each treatment was replicated six times. It was not practical to keep untreated checks for either the codling moth or mites. The trees, which were reasonably uniform in size and vigor, were well pruned to permit thorough spraying and were sufficiently far apart so that there was little or no drift of spray to adjoining trees. All sprays were applied with a power sprayer using from 600 to 700 pounds pressure. Spray brooms equipped with four nozzles and Number 3 discs were used. Two lines of hose were operated. The same two operators made all applications. All spraying was done from the ground position, the sprayman first going to the center of the tree, from where he sprayed it from all angles then completed the operation by going around the tree on the outside. No dormant or delayed dormant sprays had been applied. Due to favorable weather, mildew, which is often serious on this variety, did little damage. The common red spider, which is very injurious in some orchards in the vicinity, was not numerous enough in the plots to warrant taking records. Brown mite injury was quite severe under the treatments which gave the poorest control. Probably our best measure of the mite population under the different treatments was the count of overwintering eggs in the calyx basins of fruits at harvest. Egg laying appeared to be complete at that time. This record is given in table 1.

There was a heavy set of fruit. No thinning was done with the result that the size was somewhat below normal for the variety. The number and wormyness of all windfalls and harvested fruits were recorded. The June drop, which was very light, was included. The record includes all larvae that successfully entered. It is felt that the number of worms that enter with a treatment is a more valuable measure of effectiveness than the percentage of wormy fruit alone. With the less efficient treatments two, three or even five or more larvae may enter a single fruit. An analysis of covariance of the data was made. Such a study permits adjusting the record for all treatments to a uniform crop basis, thus eliminating a very important variable.

All DDT used was of a single brand of 50 per cent wettable powder. In all cases the DDT was used at the rate of 1.5 lbs. per 100 gallons of water. This has become the standard codling moth control dosage in western Colorado. The parathion wettable powder was of 25 per cent concentration. The calyx application was not made with any of the treatments. The amounts of materials used per 100 gallons of water are given in table 1. Systematic examinations of the foliage and fruit of each plot were made to determine the phytotoxic effects of the various spray combinations.

Discussion.—It will be seen from table 1 that DDT was the most effective codling moth control material. Four applications,

[1] Scientific Series Paper No. 303, Colorado Agricultural Experment Station.

two consisting of lead arsenate, with kerosene and soap against the first brood and two consisting of fixed nicotine[1] and summer oil against the second brood permitted approximately four times as many worms to enter the fruit as did four applications of DDT. Four applications of DDT gave significantly better codling moth control than four applications of parathion, 1 pound, and 2 pounds, per 100 gallons. Two pounds of parathion per 100 gallons of water was no more effective than 1 pound. Two and one-half ounces of parathion added to a DDT treatment as a possible mite control did not affect the codling moth control. The superiority of DDT over methoxychlor for codling moth control was highly significant. Results from the combinations of DDT with the acaricides, dinitro compound,[2] wettable sulfur, selenium spray[3] and parathion were not significantly different. The methane spray[4] apparently did reduce the effectiveness of DDT as there is a significant difference between the results with this combination and the ones just mentioned. Two applications of DDT were found to be very inadequate. This schedule was abandoned and additional applications made to prevent a heavy loss of fruit. The difference in favor of four applications of DDT over three applications was highly significant. There was an insignificant difference in favor of five applications of DDT over four applications. Five applications of DDT may be advisable in problem orchards or during seasons of late codling moth activity.

Dinitro compound, 12 ounces, wettable sulfur 6 and 8 pounds and selenium spray 1 quart when used with 100 gallons of the standard strength of DDT gave efficient and equal control of the clover mite. None of the combinations show phytotoxic

[1] Black Leaf 155.
[2] DN-111.
[3] Selocide.
[4] IN-4200.

Table 1.—Results of tests to control codling moth and clover mite on Jonathan apples. Paonia, Colorado. Season of 1948.

Materials and Quantities per 100 Gallons	No. of Sprays	Codling Moth					Mean, Clover Mite Eggs per Sample
		Mean, harvest and wind-fall fruits	Mean, worms per treatment	Adjusted mean, worms per treatment	Worms per 1000 apples	Treatment rank	
3. DDT, 1.5 lbs.; dinitro compound[1]—2.75 lb. 1st. 4 applications. DDT 1 lb.; dinitro compound—0.75 lb. fifth application	5	5011	366.3	281.0	64	1	3.6
10. DDT 1.5 lbs.; wettable sulfur 8 lbs. in first 2 applications, 6 lbs. in last 2	4	4691	440.3	400.8	91	2	0.4
9. DDT 1.5 lbs. selenium spray[2]—1 quart and 1 oz. Spreader 8	4	5280	597.7	474.1	107	3	0.6
5. DDT 1.5 lbs.; parathion (25%) 2.5 oz.	4	3947	411.3	477.9	108	4	158.4
1. DDT 1.5 lbs.; dinitro compound—0.75 lb.	4	5469	761.0	610.3	138	5	2.2
8. Parathion (25%) 2 lbs.	4	3500	761.5	891.9	202	6	0.6
6. Parathion (25%) 1 lb.	4	3738	843.0	939.4	213	7	5.0
4. Methoxychlor—3 lbs.; alkyl sulfide[3]—1 pint, first 3 applications	4	4193	968.2	1012.6	229	8	423.8
11. DDT 1.5 lbs.; with methane spray[4]—1 lb. in first 3 applications	4	4826	1132.2	1073.4	243	9	349.4
2. DDT 1.5 lbs.; dinitro compound—0.75 lb.	3	3417	980.5	1122.8	254	10	12.0
0. DDT 1.5 lbs.; dinitro compound—0.75 lb.	3	5211	1328.0	1214.1	275	11	10.8
7. Arsenate of lead 3 lbs.+kerosene-soap mixture, first 2 applications; fixed nicotine 3 lbs.; summer oil 1 quart; last 2 applications	4	3770	1537.8	1629.7	369	12	77.0
Difference required for significance							
5 per cent point				602.8			106.2
1 per cent point				803.0			141.9

[1] *DN-111*—Triethanolamine salt of dinitro-o-cyclohexylphenol.
[2] *Selocide*—Potassium-ammonium-seleno-sulfide.
[3] *IN-4200*—Alkyl-2-thiazolinyl sulfides.
[4] *Neotran*—bis (p-chlorophenoxy) methane.
[5] *Triton B-1956*—Phthalic glycerol alkyd resin.

effects. Two and one-half ounces of parathion to 100 gallons of DDT spray gave partial but unsatisfactory clover mite control. One pound and 2 pounds of the parathion gave clover mite control equal to the dinitro compound, sulfur and selenium treatments. The combinations of one pint of alkyl sulfide with 3 lbs. methoxychlor, and 1 lb. methane spray with 1.5 lbs. of DDT to 100 gallons of water gave little if any clover mite control. Because of severe injury to the foliage the alkyl sulfide was omitted from the 4th application. Foliage injury was not noted on the methane spray-DDT plots but at harvest the fruits showed highly colored spots where drops of spray had collected. Fruits from methane spray plots lost moisture rapidly and shriveled in storage. The treatment with fixed nicotine and summer oil gave partial but unsatisfactory clover mite control.

Wettable sulfur is our standard material for powdery mildew control and usually must be used in some of the codling moth applications; however, the disease was not prevalent enough this season to permit readings.

SUMMARY.—Combination sprays were tested for the control of the codling moth and the clover mite. DDT proved to be the most effective codling moth control material. It was equally effective in combination with dinitro compound, wettable sulfur, selenium and parathion. Two and three applications of DDT were unsatisfactory. The superiority of four applications over two and three was highly significant. Five applications were superior to four but not significantly so. Four applications of 1 and 2 lbs. of parathion and 3 lbs. of methoxychlor failed to give satisfactory codling moth control. A treatment consisting of two applications of arsenate of lead on the first brood of codling moth and two of fixed nicotine with summer oil in the second brood permitted about four times as many worms to enter as did four applications of DDT. Wettable sulfur, dinitro compound, selenium compound and parathion gave equal control of the clover mite. Methane spray and alkyl sulfide failed to give satisfactory mite control and both cause foliage and fruit injury.

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Comparative Effectiveness of Various Organic Insecticides Against the Oriental Fruit Moth

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The standard insecticidal control measure for the oriental fruit moth on peaches in South Carolina consists of two applications of 2 pounds of a 50 per cent wettable DDT to 100 gallons of water, 5 and 3 weeks prior to ripening (Ferree & Nettles 1948),[3] but observations made during 1948 indicate that probably additional applications earlier in the season may be required to reduce the injury by the oriental fruit moth. Frequent inspections of several orchards in the Piedmont section of South Carolina showed that there was a heavy infestation of oriental fruit moths early in the season and that this insect was causing considerable damage to the green peaches. In two or three orchards 20 to 25 per cent of the dropped peaches, at the middle of May, were infested with oriental fruit moth larvae.

Several growers applied extra applications of DDT and these orchards were watched for a "build-up" of mites. Almost all of these orchards showed more mite damage than orchards that had not re-

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ceived the extra DDT sprays. Even though the weather this year was not too favorable for mites, they did considerable damage in some orchards.

There is, also, another potential danger connected with the use of more than two applications of DDT, and that is the increase in toxic residues. Therefore, there is a definite need for a material which will control the oriental fruit moth and if possible the curculio, without causing a build-up of mites or leaving a toxic residue.

The experiment described in this article was designed primarily to compare the effectiveness of DDT, DDD, the methoxy analog of DDT, and parathion against the oriental fruit moth. Fortunately there was a sufficient infestation of second brood curculio to provide additional information regarding the comparative effectiveness of these insecticides against this insect.

MATERIALS AND METHODS.—The materials, the dates of application, and the strength used in this experiment are given in table 1.

All materials were applied with a four nozzle boom attached to a power sprayer operated at 300 pounds of pressure and approximately 4 gallons of spray were applied to each tree per application.

An orchard of 8-year old Elberta trees was selected for this experiment. The set of fruit in this orchard ranged from light to average. Due to the light crop on the greater part of the orchard, the grower had not followed a very vigorous spray schedule for the control of curculio and had not applied any DDT sprays. The spray normally recommended to be applied 1 month before harvest for control of curculio was omitted from the test section of this orchard, but dusting sulphur was applied prior to harvest for the control of brown rot.

Table 1.—Materials used in tests on Oriental fruit moth.

TREAT. NO.	MATERIAL	INSECTICIDE PER 100 GALLONS: 1st Application June 16 & 17	2nd Application June 30
1	DDT, 50% Wettable[1]	2 lbs.	2 lbs.
2	DDT, 50% Wettable	2 lbs.	1 lb.
3	Methoxy analog of DDT, 50% Wettable[1]	2 lbs.	2 lbs.
4	DDD, 50% Wettable[2]	2 lbs.	2 lbs.
5	Parathion, 25% Wettable[3]	12 ozs.	12 ozs.
6	Parathion, 25% Wettable	6 ozs.	6 ozs.
7	Check—Untreated	—	—

[1] E. I. DuPont De Nemours and Company, Wilmington, Delaware.
[2] Rohm and Haas Company, Philadelphia, Pennsylvania.
[3] American Cyanamid Company, 30 Rockefeller Plaza, New York, N. Y.

Only trees that would pick at least 1.5 bushels were sprayed and single tree plots replicated six times were used. The peaches on the test plots were allowed to remain on the trees for approximately 1 week after the grower had harvested the remainder of the orchard. All of the peaches on the test plots were harvested on the same day, July 20. A sample of 50 peaches was selected at random from the fruits harvested from each of the test trees. These peaches were cut on the following day and the data recorded as follows: per cent wormy peaches, per cent oriental fruit moth injured peaches (this figure includes the peaches that contained oriental fruit moth larvae and all other peaches that were suspected of having been damaged by oriental fruit moth), per cent oriental fruit moth larvae, and per cent curculio grubs. The later two categories include all the worms that were present in the peaches at the time

Table 2.—Comparative effectiveness of organic insecticides against oriental fruit moth and curculio.

TREATMENT NO.	MATERIAL	WORMY PEACHES	FRUIT MOTH INJURED PEACHES	FRUIT MOTH LARVAE	CURCULIO GRUBS
		Per Cent			
1	DDT	36.33	10.00	4.00	27.00
2	DDT	46.00	9.00	2.33	31.00
3	Methoxychlor	20.67	11.53	5.33	4.67
4	DDD	31.67	12.33	5.00	14.00
5	Parathion	9.33	2.76	1.33	3.00
6	Parathion	16.67	9.33	1.33	8.00
7	Check—Untreated	39.67	17.67	9.00	17.33
Least Significant Difference, 5%		12.60	7.59	5.34	15.50
Least Significant Difference, 1%		16.97	10.23	7.21	20.90

they were cut, and these figures are based on the total of 300 peaches.

The data were subjected to analysis of variance and are presented in table 2.

DISCUSSION OF RESULTS.—Although a high percentage of the twigs and the green peaches showed signs of oriental fruit moth damage at the time the first application was made, the fruit moth infestation at harvest was less than expected. A majority of the plots showed a high percentage of wormy peaches, but most of this damage appears to have been caused by curculio.

An examination of the data in table 2 shows that the methoxy analog of DDT and parathion at the two rates of application were the only treatments that gave a significant reduction over the untreated check in the percentage of wormy peaches. All of the treatments showed a marked reduction in the per cent oriental fruit moth injured peaches and per cent oriental fruit moth larvae, but the 12 ounce dosage of parathion was the only treatment that was significantly more effective than the others. However, the 6 ounce dosage of parathion was equally as effective as the DDT treatments. DDT was slightly more effective than the methoxy analog and DDD, but there appeared to be no significant difference between the two DDT treatments. The figures in the last column indicate that there was a relatively heavy infestation of curculio grubs in some of the plots, particularly the two DDT treatments. It is doubtful that DDT permitted a build-up of curculio, although there were more curculio grubs in the DDT plots than in the check. However, it is evident from these results that an additional insecticide for the control of curculio is required when DDT is used for the control of the oriental fruit moth. The methoxy analog of DDT gave good control of the curculio, but DDD was ineffective. The results with parathion were outstanding. The 12 ounce dosage of this material was slightly more effective than two pounds of the methoxy analog of DDT, and the 6 ounce dosage caused a reduction of more than 50 per cent in the curculio infested fruit as compared with the untreated check.

Although parathion was more effective against both the oriental fruit moth and curculio than any of the other materials, and while it appears that at last a compound has been discovered which will control both of these major pests of peaches, probably without causing a build-up of mites, it must be remembered that this compound has been reported to be highly toxic to man or other warm blooded animals. It should be used with utmost caution. However, no ill effects upon the operators were observed during this experiment. No attempt was made to determine the amount of parathion residue on the fresh peaches in these plots; but an analysis of processed peaches from these plots showed no parathion present. In another experiment where 2 pounds of 25 per cent wettable parathion to 100 gallons of water was applied to individual trees and where some of the trees were sprayed as many as nine times with the last application made only 6 days before harvest, there appeared to be a very small amount of residue. In fact, only 1.5 parts per million of parathion was recovered from the peel from the peaches on the trees that received the nine applications.

The methoxy analog of DDT was the only other material that showed promise against both the oriental fruit moth and curculio. It was somewhat less effective on both of these pests than parathion and was slightly less effective than DDT on the oriental fruit moth; but due to the fact that it has been reported to be much less toxic to warm blooded animals than either of these materials, further study is warranted.

SUMMARY.—DDT, the methoxy analog of DDT, dichlorodiphenyl dichlorethane and parathion were tested in the field against the Oriental fruit moth and second brood curculio on peaches.

Parathion and the methoxy analog of DDT were the only two materials that showed promise against both insects.

All of the treatments gave a marked reduction of Oriental fruit moth over the untreated check.

Parathion was more effective against the Oriental fruit moth than was DDT.

DDT was slightly more effective against oriental fruit moth than the methoxychlor or dichlorodiphenyl dichloroethane.

There was no significant difference in the results from applying a dosage of 2 pounds of a 50 per cent wettable DDT in two applications and a dosage of 2 pounds in the first application with 1 pound in the second.

Oriental Fruit Moth Control with DDT and Parathion

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During May and June, 1948 the writers carried on field experiments in peach orchards in southern, central and northern New Jersey to control the plum curculio. The insecticides tested were lead arsenate, benzene hexachloride, parathion and chlordan. In two of these experiments the materials were applied twice ten days apart, the first application going on at about the time the husks were off the young peaches. The dates were May 20th and May 30th in one orchard in central New Jersey and May 29th and June 9th in the other orchard in northern New Jersey. These dates happened to correspond with the period of first brood oriental fruit moth activity in these two orchards.

While examining dropped peaches under certain trees in the various plots during June to determine curculio control, it was observed there was a difference in the number of wormy drops due to oriental fruit moth. Therefore a separate record of wormy drops due to Oriental fruit moth was kept. The data obtained are set forth in table 1.

The data in table 1 show that first brood oriental fruit moth injury, as far as dropped fruit was concerned, was quite low on the parathion sprayed plot in both the central and northern New Jersey orchards.

Another method of checking the effect of the different spray treatments presented itself. This was by determining the number of injured twigs on the trees. On June 24th the 6 "count" trees in each plot in the Warren County orchard were gone over carefully and the number of injured twigs on each tree recorded. The data obtained are set forth in table 2.

The data in table 2 show that there were no peach twigs showing injury by first brood Oriental fruit moth on the parathion treated plot. All the other treatments showed some twigs injured on every tree. The comparatively low twig injury on the lead arsenate and the benzene hexachloride plots next to the parathion may have resulted from the effects of the parathion either by spray drift or interchange of moths between plots.

The unexpected results obtained in reducing first brood oriental fruit moth with parathion used for curculio control led to further experiments with this new insecticide to control the later broods of the oriental fruit moth. Plots were set up in an orchard in central New Jersey and in an orchard in northern New Jersey to compare parathion with DDT as a control for second and third brood oriental fruit moth. The plot set up consisted of four rows running across several varieties in each orchard. In the central New Jersey orchard the sprays were applied with a single nozzle gun, the operator working from the ground. In the northern New Jersey orchard a speed sprayer was used to apply the sprays.

The plot treatment in the central New Jersey orchard was as follows: Plot 1 was sprayed with DDT (50 per cent wettable) 2 pounds on July 15 and again on August 6 against third brood oriental fruit moth. Plot 2 was sprayed with parathion (25 per cent wettable) 1 pound on June 20 against second brood oriental fruit moth

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

Table 1.—Number of oriental fruit moth wormy drops on 6 trees in several plot treatments.

Plot No.	Treatment	Total Drops		Wormy		Moths per Tree	
		Middlesex	Warren	Middlesex	Warren	Middlesex	Warren
1	Benzene hexachloride	5646	2574	10	122	1.7	20.3
2	Lead Arsenate-Lime	3520	3118	33	18	5.5	3.0
3	Parathion	6084	2534	2	0	0.3	0.0
4	Chlordan	3520	2300	16	40	2.7	6.7
5	Check	7846	—	36	—	6.0	—

Table 2.—Number of twigs injured by first brood oriental fruit moth larvae on six trees in plots sprayed differently.

Tree No.	Number Injured Twigs on: Benzene hexachloride	Chlordan	Lead Arsenate-Lime	Parathion	Benzene hexachloride
1	15	8	10	0	18
2	31	26	2	0	7
3	22	13	6	0	15
4	38	24	7	0	6
5	9	8	6	0	9
6	17	9	8	0	2
Totals	132	88	39	0	57
Ave. per Tree	22	14.7	6.5	0	9.5

and again on July 15 and August 6 against third brood oriental fruit moth. Plot 3 was left unsprayed to serve as a check. Plot 4 was sprayed with DDT (50 per cent wettable powder) 2 pounds on June 20 against second brood oriental fruit moth and again on July 15 and August 6 against third brood oriental fruit moth.

Oriental fruit moth control was determined by examining all the fruit on one tree in each plot on four varieties ripening at different periods following the last spray application on August 6.

In examining the fruit for oriental fruit moth injury all the fruit on the selected count tree, including the dropped fruit, was examined for visible oriental fruit moth injury. An attempt was made to separate the visible injury caused by second brood larvae from the visible injury caused by third brood larvae. After the visible injured fruits had been separated from the apparently sound fruit a portion of this apparently sound fruit was sliced to determine the percentage of so-called invisible injury.

The results obtained from the examination of fruits from four varieties harvested at different dates following the last spray application on August 6 are set forth in table 3.

The first thing to be noted in table 3 is the high percentage of oriental fruit moth injury on the unsprayed check trees. This ranged from 40 per cent in the Triogem to 92 per cent on the Elberta. The second interesting fact brought out by the data is that the one spray of DDT and parathion applied for second brood oriental fruit moth did not materially improve the control as compared to DDT spraying for third brood alone. It is to be noted in table 3 that second brood injury on the check plot ran consistently higher than in the treated plots. This may be due to the fact that the injury was so high on the unsprayed check it was difficult to separate second brood from third brood injury.

Table 3.—Results of DDT and parathion sprays used against second and third brood oriental fruit moth compared to DDT used against third brood.

Plot No.	Treatment	No. Peaches Examined	Per Cent Injured Visible 2nd Brood	Visible 3rd Brood	Invisible 3rd Brood	Per Cent Injured
	Triogem, Harvested Aug. 10 and 17					
1	DDT 3rd Brood	700	5.6	0.0	2.0	7.4
2	Parathion 2nd & 3rd Broods	700	3.0	0.0	0.0	3.0
3	Check	700	15.7	10.0	20.0	40.4
4	DDT 2nd & 3rd Broods	700	2.1	0.0	4.0	6.0
	Red Rose, Harvested Aug. 14 and 18					
1	DDT 3rd Brood	700	2.8	0.1	3.0	5.9
2	Parathion 2nd & 3rd Broods	600	2.0	0.0	0.0	2.0
3	Check	700	13.6	12.9	38.0	54.4
4	DDT 2nd & 3rd Broods	600	5.0	0.3	3.0	8.2
	Summercrest, Harvested Aug. 24 and 28					
1	DDT 3rd Brood	550	7.1	0.2	2.0	9.1
2	Parathion 2nd & 3rd Broods	550	4.0	0.5	2.2	6.7
3	Check	550	17.4	52.2	60.0	87.8
4	DDT 2nd & 3rd Broods	550	5.6	1.1	10.0	16.0
	Elberta, Harvested Aug. 30, and Sept. 1					
1	DDT 3rd Brood	400	5.7	8.5	28.0	38.2
2	Parathion 2nd & 3rd Broods	400	2.0	1.7	2.6	6.2
3	Check	400	15.2	68.2	52.5	92.2
4	DDT 2nd & 3rd Broods	400	5.7	14.0	13.3	30.2

Table 4.—Results of DDT and parathion sprays used against second and third brood oriental fruit moth compared to DDT used against third brood alone.

Plot No.	Treatment	No. Peaches Examined	Per Cent Injured Visible		Invisible 3rd Brood	Total Per Cent Injured
			2nd Brood	3rd Brood		
	Triogem, Harvested Aug. 16					
1	Check (no spray)	—	—	—	—	—
2	DDT 3rd Brood	300	6.0	0.0	0.0	6.0
3	DDT 2nd & 3rd Broods	300	5.7	0.0	2.0	7.5
4	Parathion 2nd & 3rd Broods	300	1.7	0.3	1.0	2.7
	Summercrest, Harvested Aug. 23 and 27					
1	Check (no spray)	300	25.0	25.0	47.0	73.3
2	DDT 3rd Brood	300	13.3	0.0	11.0	22.9
3	DDT 2nd & 3rd Broods	300	8.0	0.0	10.0	17.2
4	Parathion 2nd & 3rd Broods	300	2.7	0.0	3.0	5.7
	N. J. #83, Harvested Sept. 1 and 2					
1	Check (no spray)	300	12.7	51.0	37.7	77.3
2	DDT 3rd Brood	300	8.7	0.7	9.0	17.2
3	DDT 2nd & 3rd Broods	300	6.0	2.7	17.0	23.9
4	Parathion 2nd & 3rd Broods	300	4.0	4.7	29.0	35.0

A further examination of the data in table 3 will show that DDT and parathion were effective in holding third brood injury to a minimum on three varieties, Triogem, Red Rose and Summercrest, all harvested within 3 weeks after the last spray was applied. When it came to Elberta, harvested approximately 4 weeks after the last spray both DDT and parathion were beginning to lose their effectiveness. Parathion, however, was showing up better than the DDT treatment.

The experimental set-up in the Warren County orchard in northern New Jersey was much the same as that in the central New Jersey orchard. Parathion and DDT were used once against second brood and twice against third brood on two plots and on a third plot DDT was used twice against third brood only. Spray applications were made with a speed sprayer and the dates of application were June 24 for the one second brood application and July 23 and August 7 for the two third brood spray applications. A single row of trees was left unsprayed to serve as a check.

Three varieties ripening roughly 1, 2 and 3 weeks after the last spray application were examined for oriental fruit moth. Larval injury to the fruit was determined in the same manner as that outlined for the plots in the central New Jersey orchard. The results obtained are set forth in table 4.

The data in table 4 show that there was not much difference between the second brood injury between the plots receiving second and third brood sprays compared to the plot receiving third brood sprays only. Against third brood larvae the DDT and parathion were effective especially as regards visible third brood injury. However, on both Summercrest and N. J. #983, invisible worm injury ran fairly high indicating that the spray coverage was not very effective after two or three weeks.

Summary.—While carrying on field experiments in the spring of 1948 on peaches for control of plum curculio with several insecticides, the authors discovered that parathion was giving excellent control of the concurrent first brood of oriental fruit moth. This unexpected observation led to the inclusion of parathion in further experiments for control of later broods of oriental fruit moth.

Field plots were organized in widely separated sections of the state to test the effectiveness of two third brood DDT sprays with one second and two third brood sprays of parathion and DDT. In one orchard an unsprayed check plot was included. Second brood injury was separated from third brood injury in data counts.

Results on the unsprayed check trees showed a high percentage of injury ranging from 40 per cent on Triogem to 92 per cent on Elberta. On the treated plots, it was found that two third brood sprays

of DDT were not materially less effective in reducing total injury than one second brood and two third brood parathion or DDT sprays. On varieties harvested within 3 weeks of the last application of spray material, oriental fruit moth infestation was held to a low percentage. However, on varieties harvested over 3 weeks after the last spraying, worm injury was considerably higher. Both parathion and DDT gave good control but parathion was slightly more effective.

Control of the Red-Banded Leaf Roller[1]

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A series of tests using various insecticides and acaricides were set up for the control of colding moth and the European red mite. All of the insecticides used proved effective against the codling moth. Eight of the plots were free from codling moth injury, and the highest infestation on any plot was approximately 1 per cent. The red mite population was negligible on all plots, making it impossible to get any data on the effectiveness of any spray combinations. The experiment included 16 rows of Stayman apples, each row having 6 trees. A freeze in the early spring left an average of approximately 2 bushels of apples per tree. However, the original program was carried through as planned One plot in the experiment had the dormant and the delayed dormant oil spray omitted. All of the other plots were sprayed with a 3 per cent oil emulsion in the late delayed dormant stage. During the blooming period it became evident that the red banded leaf roller, *Argyrotaenia velutinana* (Wlkr.), was going to be a major pest in this orchard. Observations at various times during the first brood showed that the damage varied from perfect control on some plots to serious injury on others, depending upon the insecticide used.

The last spray in the program designed for codling moth and European red mite was completed on June 22. It was expected that none of the materials would have sufficient residual effect to last until the second brood was due to appear. Therefore, on July 19, about 10 days after the second brood moths had become active, the entire block was treated with dichlordiphenyl dichloroethane with the result that no further injury occurred from either the second or the third brood larvae.

A block of trees adjacent to the experimental plot did not have a complete spray schedule due to the light crop caused by freezing. A heavy population of leaf rollers in this block made it satisfactory for tests against the second brood. A series of plots were selected for tests with dichlorodiphenyl dichloroethane, parathion, and combinations of these materials with DDT and fungicides against the second brood. The data obtained on the leaf roller with the original program designed for codling moth and red mite is shown in table 1, and that obtained with sprays designed especially for leaf rollers is shown in table 2.

DISCUSSION.—The data presented in table 1 without an explanation is somewhat misleading. It will be noted that the water sprouts on plots 8, 9, 11, 13 and 16 were comparatively free of injury on June 10. It will also be noted that parathion was used in the petal-fall and the first cover in all of these plots with some receiving two other applications. Observations on these plots showed that they remained practically free from leaf rollers throughout the activity of the first brood moths and until July 10 at which time the second brood worms became active. During the period from July 10 until July 19, at which time the entire block was sprayed with dichlorodiphenyl dichloroethane the moths of the second brood infested all plots including the ones treated with parathion. The data shows injury to fruit on the plots that had no infestation on June 10. The injury to the apples on these plots was caused by the second brood larvae between July 10 and July 19. The data on plot 12 showed that parathion did not remain toxic during the 30 day period that elapsed between the petal fall and second cover spray. The records on water sprouts from this plot, taken on June 10, showed a high degree of infestation. Plot 3, where the delayed dormant oil was

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Table 1.—Per cent water sprouts infested on June 10 and fruit injured at harvest by the red banded leaf roller.

MATERIALS USED	APPLES EXAMINED	INJURED BY LEAF ROLLER	WATER SPROUTS EXAMINED	WATER SPROUTS INFESTED
3 lbs. lead arsenate, 3 lbs. lime in 4 sprays	1048	11.54%	195	42.0%
1 lb. DDT in 4 sprays. 2.5 lbs.bis(parachlorophenoxy) methane[1] in second and third covers	1132	50.17	211	70.0
1 lb. DDT in 4 sprays. 2.5 lbs. bis(parachlorophenoxy) methane[1] in first and second covers	1581	78.81	269	94.4
1 lb. DDT in 4 sprays. 1.25 lbs. Dinitro compound[2] in second and third covers	848	63.56	154	65.4
1 lb. DDT in 4 sprays. 1.25 lbs. Dinitro compound[2] in first and second covers	1006	66.30	155	62.5
1 lb. DDT plus 3 lbs. lead arsenate in 4 sprays	726	15.84	132	53.0
3 lbs. lead arsenate, 3 lbs. lime in petal fall, 2 lbs. DDT in 2 other sprays at 35-day intervals	532	27.06	154	45.4
1 lb. Parathion[3] in 4 sprays	576	14.43	184	0
1 lb. Parathion, 0.5 lb. DDT in 4 sprays	585	6.15	151	.132
3 lbs. lead arsenate, 3 lbs. lime in petal fall, 1 lb. DDT in first and second covers, 1 lb. Parathion in third cover	556	22.12	170	75.8
1.5 lbs. Parathion in 4 sprays	573	6.80	147	0
1 lb. Parathion in petal fall, 1 lb. DDT in first cover, 1 lb. Parathion in second cover, 1 lb. DDT in third cover	831	24.78	144	42.3
1 lb. Parathion in petal fall and first cover. 1 lb. DDT in second and third covers	601	6.48	203	0
1 lb. 40% Chlordan[4] in 4 sprays	754	39.12	155	67.08
1 lb. 40% Chlordan and 0.5 lb. DDT in 4 sprays	830	31.92	162	60.4
1 lb. 40% Chlordan and 1 lb. Parathion in 4 sprays	1004	9.66	150	.133

[1] *Neotran*—bis (p-chlorophenoxy) methane furnished by the Dow Chemical Co., Midland, Michigan.
[2] Triethanolamine salt of dinitro orthocyclohexyl phenol—"*DN-111*," Dow Chemical Co.
[3] Parathion—25 per cent wettable powder furnished by American Cyanamid Co., New York.
[4] *Dowklor* 40 per cent chlordan powder furnished by the Dow Chemical Co.

omitted, had the heaviest infestation of leaf rollers of any plot in the series. This was noticeable from the degree of foliage injury and from the number of egg clusters present. Plots 2 to 5 inclusive received the same insecticides in the spray schedule. The arsenate of lead program used in plot 1 prevented injury to the applies from the first brood moths. However, it did not prevent feeding on the foliage as shown in the data. It was evident that later application of lead arsenate would have been necessary to prevent serious injury from second and third brood worms. The plots sprayed with DDT or chlordan had a high degree of infestation all during the activities of the first brood on both the apples and foliage.

The data in table 2 shows that all of the spray combinations used gave excellent control of the leaf roller, except the 0.5 pound of 50 per cent wettable dichlorodiphenyl dichloroethane powder and 0.5 pound 25 per cent wettable parathion. There was apparently no reduction in the toxicity of either dichlorodiphenyl dichloroethane or parathion when it was combined with DDT or DDT and sulfur. There was considerable foliage injury on all plots where sulfur was used. The heaviest injury occurred where lime-sulfur was used. This injury, however, was no greater than would have been expected from the sulfur sprays alone with the temperature reaching a maximum of 99° F. the day the application was made. No injury occurred on any of the plots where sulfur was not combined with the spray.

SUMMARY.—Parathion at the rate of 4 ounces of the toxicant to 100 gallons of spray gave practically 100 per cent control of the first brood red banded leaf roller when used in the petal fall and first cover spray. Lead arsenate when used in four sprays gave fair control of the injury to fruit, but the water sprouts were infested all during the activities of the first brood. The low toxicity of lead arsenate to the larvae on foliage would permit building up of a second and third brood population which would require several additional sprays to give satisfactory control. DDT and chlordan proved unsatisfactory

Table 2.—Control of the second brood red banded leaf roller.

SPRAYED	EXAMINED	MATERIALS USED PER 100 GALLONS OF SPRAY	LEAVES EXAMINED	LARVAE
July 14	July 19	1 qt. 25% dichlorodiphenyl dichloroethane[1] emulsion	50	0
July 14	July 19	1 lb. 25% wettable Parathion	50	0
	July 19	Check	50	90
July 26	July 29	0.5 lb. 50% dichlorodiphenyl dichloroethane wettable powder	50	11
	July 29	Check	50	82
July 26	July 29	1 lb. 50% dichlorodiphenyl dichloroethane wettable powder	50	2
July 26	July 29	1 pt. 25% dichlorodiphenyl dichloroethane emulsion	50	1
	July 29	Check	50	81
July 30	Aug. 2	1 pt. 25% dichlorodiphenyl dichloroethane emulsion, 2	50	4
	Aug. 6	lbs. 50% DDT powder and 6 lbs. wettable sulfur	50	1
July 30	Aug. 2	1 pt. 25% dichlorodiphenyl dichloroethane emulsion, 2	50	1
	Aug. 6	lbs. 50% DDT powder	50	1
July 30	Aug. 2	0.5 lb. 25% wettable Parathion, 6 lbs. wettable sulfur	50	3
	Aug. 6		50	4
July 30	Aug. 2	1 qt. 25% dichlorodiphenyl dichloroethane emulsion, 2	50	1
	Aug. 6	lbs. 50% DDT powder and 6 lbs. wettable sulfur	50	0
July 30	Aug. 2	1 pt. 25% dichlorodiphenyl dichloroethane emulsion, 2	50	1
	Aug. 6	lbs. 50% DDT powder and 6 qts. liquid lime sulfur	50	0
July 30	Aug. 2	1 lb. 50% wettable dichlorodiphenyl dichloroethane	50	1
	Aug. 6	powder and 6 lbs. wettable sulfur	50	0
July 30	Aug. 2	1 qt. 25% dichlorodiphenyl dichloroethane emulsion, 2	50	1
	Aug. 6	lbs. 50% DDT powder and 6 qts. liquid lime sulfur	50	1
	Aug. 2	Check	50	73

[1] *Rothane* emulsion and wettable powder furnished by Rohm & Haas Co., Philadelphia, Pa.

for the control of the first brood leaf roller. The elimination of the delayed dormant oil spray caused a noticeable increase in the leaf roller population in plot 3. Dichlordiphenyl dichloroethane at the rate of 1 quart or 1 pint of the 25 per cent emulsion to 100 gallons of spray gave excellent control of the second brood leaf roller, both in experimental plots and in commercial orchards. No additional injury occurred either from the second or third brood worms in orchards receiving one application of dichlorodiphenyl dichloroethane emulsion. One pound of the 50 per cent wettable powder was about equal in effectiveness to 1 pint of the 25 per cent emulsion. One-half pound of the 50 per cent wettable powder did not give satisfactory control. 1 pound of the 25 per cent wettable parathion powder gave perfect control, but 0.5 pound of the same material was somewhat less effective.

The tests on the compatibility of dichlorodiphenyl dichloroethane and parathion with DDT, DDT and sulfur combinations showed that the toxicity of the first two was not reduced when combined with these materials.

Foliage injury occurred on all of the plots where sulfur was used, but the injury was probably no more severe than it would have been from use of sulfur alone.

DDT and Other Insecticides to Control the Pecan Nut Casebearer

C. B. NICKELS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Experiments with DDT and other insecticides for the control of the pecan nut casebearer, *Acrobasis caryae* Grote, were conducted in Texas during 1946 and 1947. The studies included (1) field experiments carried on both years in severe infestations in the southern part of the state; (2) observations on the effects of certain late-summer sprays, applied primarily for weevil control, on the number of nut casebearer larvae that went into winter quarters; and (3) laboratory tests of certain materials of possible value in killing casebearer eggs.

FIELD TESTS.—*Methods and Materials.*—All the spraying was done from the ground with a standard power sprayer at a pressure of 500 to 600 pounds per square inch, a single-head gun being used. In 1946 the regular tests were carried on at Crystal City, Tex., on the Burkett variety of pecan. Each treatment was replicated 10 times. On April 27, 25 per cent of the nut eggs had hatched, but no larvae had entered the nuts. The first application of sprays was made on April 29.

In 1947 most of the work was done at Pearsall on Burkett, Mahan, and Stuart varieties. Each treatment was replicated 8 to 10 times. The first application was started May 7, 2 days after about 27 per cent of the casebearer eggs had hatched and about 2 per cent of the larvae had entered nuts on which eggs had been deposited.

DDT, nicotine sulfate, and lead arsenate were the materials used. Zinc sulfate, 2 pounds per 100 gallons, was added to all spray mixtures, primarily to control pecan rosette, and in certain tests it reduced the danger of arsenical burning. Zinc sulfate was also used on the trees receiving no insecticide.

Early in the season numbered tags were placed on 50 nut clusters on each of 10 trees for each treatment. At harvest time the number of nuts retained in each tagged cluster was recorded. The yield of nuts for each tree was calculated on the basis of the size of the trunk, to eliminate much of the variation resulting from differences in tree size.

RESULTS.—The results of the tests were indicated by the percentage of nuts retained in the clusters and by the final yields. Detailed information on the materials used, dates of application, and results of the tests, is given in tables 1 and 2.

In the 1946 experiments, carried on at Crystal City, the greatest percentage of nuts retained in the clusters and the highest yield were in the trees sprayed twice—with DDT on April 29 and with lead arsenate on May 4. These results were approached by a single application on May 1 of the mixture of lead arsenate, nicotine sulfate, and mineral oil. In most tests, single applications did not appear to give satisfactory control of the severe infestation attacking a light crop. There were no unsprayed trees in these tests, but results of former experiments indicated that without spraying the crop would have been nearly a total loss.

Table 1.—Results of spray experiments in the control of the pecan nut casebearer on Burkett pecan trees, Crystal City, Tex., 1946.

MATERIAL AND STRENGTH (QUANTITIES PER 100 GALLONS)	DATE OF APPLICATION	NUTS RETAINED IN TAGGED CLUSTERS OCT. 18–22	NUT YIELD PER SQUARE FOOT OF TRUNK SECTION
		Per Cent	*Pounds*
DDT:[1]			
Micronized with pyrophyllite 1.5 lb.	April 29	22.1	19.8
1.5 lb. Lead arsenate 6 lb.	April 29 May 4	48.6	35.7
1 lb.[2]	May 1	30.1	20.0
1.5 lb.[2]	May 4	24.2	19.5
Commercial wettable powder 1.5 lb.[2]	May 1	32.9	22.8
1 lb.[2]	do.	18.6	11.4
Nicotine sulfate 13 fl. oz. + summer oil 3 qt.	do.	26.4	17.2
Lead arsenate 6 lb. + nicotine sulfate 13 fl. oz. + summer oil 3 qt.	do.	40.2	25.0
Differences required for significance:			
P=0.01	—	13.5	10.6
P= .05	—	10.2	8.0

[1] DDT was used in a 50 per cent mixture throughout. Figures given indicate the quantity of actual DDT in the spray mixture.
[2] Used with soybean flour 2 oz., lime 2 oz., and summer oil 2 qt.

Table 2.—Results of spray experiments in the control of the pecan nut casebearer, Pearsall, Tex., 1947.

Material and Strength (Quantities per 100 Gallons)		Nuts Retained in Tagged Clusters, Oct. 11–14	Nut Yield per Square Foot of Trunk Section
First Application, May 7	Second Application, May 13		
	Burkett Variety	*Per Cent*	*Pounds*
DDT[1] 1 lb.[2]	Nicotine sulfate 13 fl. oz.+summer oil 2 qt.	32	43
DDT 1 lb.[2]	Lead arsenate 6 lb.	32	31
DDT 1 lb.[2]	Same as first application	32	47
DDT 1 lb.+hexaethyl tetraphosphate[3] 8 fl. oz.	Hexaethyl tetraphosphate 8 fl. oz.	25	39
Nicotine bentonite (nicotine 7%) +DDT (17%) 3 lb.[2]	Same as first application	30	39
Xanthone (62%)+DDT (25%) 3 lb.	Same as first application	24	41
Lead arsenate 6 lb.+nicotine sulfate 13 fl. oz.+summer oil 2 qt.	Nicotine sulfate 13 fl. oz.+summer oil 2 qt.	33	32
Nicotine bentonite nicotine (14%) 3 lb.	Same as first application	32	49
Check	Check	15	20
Difference required for significance	(P=0.05)	—	18
	Stuart and Mahan Varieties		
DDT 1.5 lb.	—	—	45
DDT 1.5 lb.+summer oil 2 qt.	—	—	42
DDT 2 lb.+summer oil 2 qt.	—	—	44
DDT 1.5 lb.+benzene hexachloride (5% gamma) 3 lb.	—	—	61

[1] Unless otherwise indicated, DDT was used in the form of a 50-per cent wettable powder. Figures given in table indicate the quantities of actual DDT, nicotine bentonite, and mixtures of nicotine bentonite with DDT, and xanthone with DDT.
[2] Used with soybean flour 3 oz., and summer oil 2 qt.
[3] Manufacturers assay, 100 per cent hexaethyl tetraphosphate. Contains 11.2 per cent of tetraethyl pyrophosphate.

In the 1947 experiments at Pearsall on the Burkett variety the highest yield of nuts was from trees that had received nicotine bentonite. All the sprayed trees gave materially better yields than the unsprayed ones.

On the Mahan and Stuart varieties the addition of oil did not appear to increase the effectiveness of DDT. Benzene hexachloride appeared to have some value when added to DDT.

No injury resulted from any of the spray treatments discussed in this paper. In more humid areas lead arsenate some-

Table 3.—Effect of sprays applied late in the summer on the numbers of nut casebearer larvae that went into winter quarters, central Texas, 1946 and 1947.

Material and Strength (Quantities per 100 Gallons)	Dates of Spray Applications	Shoots with Casebearer Hibernacula
Experiments in 1946		
DDT (50% wettable powder) 2.5 lb.[1]	Sept. 2, 10, 26[2]	1.0%
Benzene hexachloride (7.7% gamma) 5 lb.	Sept. 2[2]	1.2
Benzene hexachloride (7.7% gamma) 4 lb.	Sept. 10, 26[2]	—
Check	—	7.4
Experiments in 1947		
DDT (50% wettable powder) 3 lb.[1]	Sept. 4[2]	2.0
Lead arsenate 6 lb.	Sept. 4[2]	3.1
Chlordan (44% emulsifiable concentrate) 1 qt.	Sept. 4[2]	7.0
Check	—	10.6
Lead arsenate 6 lb.	Aug. 29, Sept. 9, 20[3]	.4
DDT (50% wettable powder) 3 lb.[1]	Aug. 29, Sept. 9, 20[3]	0
Check	—	1.8

[1] Actual DDT in spray mixture.
[2] Western variety of pecan.
[3] Burkett variety.

Table 4.—Laboratory tests of new insecticides against eggs of the pecan nut casebearer, Brownwood, Tex., 1946 and 1947.

Material and Strength (Quantities per 100 Gallons)	Per Cent of Eggs Hatched	
	Sprayed	Unsprayed
Benzene hexachloride (7.7% gamma) about 4.5 lb.	1	98
Hexaethyl tetraphosphate 8 fl. oz.[1] +DDT 1 lb.	14	96
Hexaethyl tetraphosphate 8 fl. oz.[2] +DDT 1 lb.+summer oil 2 qt.	0	98

[1] Manufacturer's assay 100 per cent hexaethyl tetraphosphate.
[2] Contains 11.2 per cent of tetraethyl pyrophosphate.

times causes serious injury to foliage.

Aphids and mites were not especially abundant at any time. Although under some conditions they increase greatly after treatment with DDT, no such increases were observed in 1946 and 1947. In 1947 certain treatments were used that should partially control aphids and mites, but these pests were not abundant enough to indicate what effect the different treatments may have had on them.

EFFECTS OF LATE-SUMMER SPRAYS.—In both years there was an opportunity to observe the effects of certain late-summer sprays of DDT (50 per cent wettable powder), benzene hexachloride (7.7 per cent gamma), lead arsenate, and chlordan (44 per cent technical grade emulsifiable concentrate) on the numbers of nut casebearers that went into winter quarters. The insecticides were applied primarily for control of the pecan weevil, but during the winter 50 shoots on each of 7 to 10 sprayed trees and on an equal number of unsprayed trees were examined for hibernacula of the casebearer. The records obtained are summarized in table 3.

LABORATORY TESTS AGAINST EGGS.—Tests were made with two of the newer materials, benzene hexachloride and hexaethyl tetraphosphate, to find out what effect they might have on nut casebearer eggs. Detailed information on these materials is given in table 4.

SUMMARY.—Field experiments carried on in Texas in 1946 and 1947 indicated that DDT is an effective material for the control of the pecan nut casebearer, *Acrobasis caryae* Grote. Against a severe infestation in a light crop in 1946 the best results were obtained with a two-application schedule, the first containing DDT as its principal ingredient and the second lead arsenate. In 1947 the best results were obtained with nicotine bentonite. Three different DDT treatments successfully controlled a heavy infestation of the nut casebearer in a good-sized nut crop on Stuart and Mahan pecan trees. In a single test benzene hexachloride appeared to have some value when added to DDT. Late summer applications of DDT, benzene hexachloride, and lead arsenate, reduced materially the numbers of casebearer larvae that went into winter quarters. In laboratory tests benzene hexachloride and a mixture of hexaethyl tetraphosphate with DDT killed a large percentage of the nut casebearer eggs.

Combating the Periodical Cicada with Insecticides

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and
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The summer of 1948 offered an opportunity for testing some of the new organic insecticides against the periodical cicada, *Magicicada septendecim* Linn. Brood V of this species covered nearly all of the eastern half of Ohio and in some areas was very abundant, causing heavy damage to orchards. There were, however, numerous local areas where damage was very light or was not even experienced.

One to 3 year old fruit trees were severely damaged and in some cases were destroyed by mutilation caused by egg-laying. Serious damage to the 2 and 3 year old wood occurred on mature trees. In some cases this interfered with the development of the fruit by causing the death of the terminals or by so reducing the flow of sap to these twigs that the fruit was dwarfed. The ovipositing females were so abundant during the 3 weeks following emergence that they weakened almost every terminal in some orchards and on isolated shade trees. By August 1 some of the mature trees had a brown periphery due to the dead and dying terminals. Many 1 to 3 year old fruit trees had more than half of their branches broken and hanging.

Emergence from the ground commenced in southern Ohio May 15 and in northeastern counties about May 26, although it began as much as a week earlier in some orchards than in others located in the same county. It continued over a long period of time, the males emerging first

[1] Mr. Charles W. Lee rendered valuable assistance in the conduct of the laboratory and cage tests.
[2] The Sherwin Williams Company, California Spray Chemical Company, and Standard Oil Company of Ohio aided greatly by supplying materials and assisting in evaluating the results.

Table 1.—Lantern globe tests.

Material	Dilution	Counts After Treatment					
		6 hrs.		24 hrs.		41 hrs.	
		dead	living	dead	living	dead	living
Tetraethyl pyrophosphate (100%)	16 oz.—100 gals.	10	0	—	—	—	—
	8 oz.—100 gals.	10	0	—	—	—	—
	4 oz.—100 gals.	10	0	—	—	—	—
Parathion (25%)	4 lbs.—100 gals.	0	10	10	0	—	—
	2 lbs.—100 gals.	0	10	5	5	10	0
Chlordan (50%)	8 lbs.—100 gals.	0	10	2	8	2	8
	4 lbs.—100 gals.	0	10	0	10	0	10
Chlordan (50% emulsion)	6.4 gals.—100 gals.	0	10	0	10	0	10
	3.2 gals.—100 gals.	1	9	1	9	1	9
Check	No treatment	0	10	0	10	0	10

and dying after the females had started egg-laying but before oviposition was completed. Following a preoviposition period of about 10 days, the females laid eggs over a period of 15 to 18 days. Due to the extended and continued emergence from the soil, the total period of damage extended over 3 to 4 weeks.

Insecticide Experiments.—This insecticidal work consisted of two phases: first, laboratory and cage tests conducted at Wooster by the senior author; and second, the grower tests which were suggested and supervised by the junior author. Due to earlier emergence in southern Ohio, field work in that area was actually under way before the laboratory tests at Wooster were started. Some of the field results were therefore used in planning the laboratory work.

Laboratory and Cage Tests, Wooster, Ohio.—Cicadas were captured and dipped in the solutions listed in table 1. After dipping, they were placed on untreated foliage in clean lantern globe cages covered with cheese cloth. The results are shown in table 1.

Wire mesh cages, with 10 cicadas each, were hung in trees in the orchard and were then sprayed with a power sprayer. Mortality records taken at different intervals after spraying are shown in table 2.

Wire cages with 10 cicadas each were hung in trees and sprayed. The cicadas were then transferred to unsprayed foliage in lantern globes in the laboratory and observed for mortality (Table 3).

Wire cages with 20 cicadas each were hung in heavily infested trees in an old orchard and the trees were *sprayed* with a power sprayer carrying 500 pounds pressure with no special attention paid to the

Table 2.—Outdoor cage tests.

Material	Dilution	Counts After Spraying					
		5 hrs.		24 hrs.		45 hrs.	
		dead	living	dead	living	dead	living
Hexaethyl tetraphosphate (100%)	12 oz.—100 gals.	10	0	—	—	—	—
	7 oz.—100 gals.	10	0	—	—	—	—
	6 oz.—100 gals.	10	0	—	—	—	—
	4 oz.—100 gals.	5	5	10	0	—	—
	3 oz.—100 gals.	3	7	5	5	10	0
DDT (50%) plus spreader	8 lbs.—100 gals.	0	10	0	10	2	8
	4 lbs.—100 gals.	0	10	3	7	3	7
Benzene hexachloride (25% gamma)	2 lbs.—100 gals.	0	10	2	8	10	0
	1 lb. —100 gals.	0	10	0	10	4	6
Check	No spray	0	10	0	10	0	10

Table 3.—Combination outdoor and indoor tests.

MATERIAL	DILUTION	20 HRS.		40 HRS.	
		dead	living	dead	living
Tetraethyl pyrophosphate (40%)	4 oz.—100 gals.	7	3	10	0
	3 oz.—100 gals.	1	9	10	0
Hexaethyl tetraphosphate (100%)	8 oz.—100 gals.	4	6	10	0
	6 oz.—100 gals.	4	6	10	0
Benzene hexachloride (25% gamma)	2 lbs.—100 gals.	0	10	5	5
Check	No spray	0	10	0	10

cages. Counts were made of dead cicadas in cages as well as on canvases spread under the tree for each treatment. (Table 4.)

Migration from surrounding trees was so heavy that living cicadas were very abundant in these trees when the 24-hour count was made.

DISCUSSION OF LABORATORY TESTS.—The cage tests indicated very poor control by DDT and chlordan. The former was used at high dosages in the form of a 50 per cent wettable powder. Chlordan was used both as a wettable powder and as an emulsion with neither form being effective. While not shown in the tables, results with chlorinated camphene were also generally unsuccessful. Benzene hexachloride, 25 per cent gamma, was slow acting, but from 50 to 100 per cent kills were usually obtained in 40 to 50 hours after spraying.

The phosphorus group, including hexaethyl tetraphosphate tetraethyl pyrophosphate and parathion, were effective with the first two being much more rapid in their action. For effective dosages there was little difference in price between these materials.

In addition to the laboratory and cage tests, several field tests were also made at Wooster. The results of these tests closely followed the laboratory findings.

GROWER TESTS.—The tests carried out by growers were in cooperation with and through the suggestions of entomologists of the Agricultural Extension Service, the State Experiment Station, and representatives of cooperating insecticide manufacturers.

Five commercial orchards were used in making the field tests. Four were mature apple orchards, and one a young peach orchard. All were heavily infested with cicadas.

Grower efforts at the beginning of emergence covered trials with the following insecticides:

DDT (50% wettable powder) —4 lbs. per 100 gallons
Benzene hexachloride (6% gamma)—4 lbs. per 100 gallons
Chlordan (50% wettable powder) —3 & 4 lbs. per 100 gallons
Chlorinated camphene (50% wettable powder) —4 lbs. per 100 gallons
Nicotine sulfate (40%) —1 pt. per 100 gallons
Parathion (15%) —1½ lbs. per 100 gallons

All of these treatments were pronounced unsatisfactory by the growers. Very few cicadas were reported killed by the materials used even when caught in the spray fog and well covered.

After experiencing failure from these materials, tetraethyl pyrophosphate 40 per cent was placed in the hands of one

Table 4.—Outdoor cage tests.

MATERIAL	DILUTION	5 HRS.		24 HRS.		
		dead	living	dead	living	dead on canvas
Hexaethyl tetraphosphate (50%)	16 oz.—100 gals.	17	3	19	1	321
" " (100%)	8 oz.—100 gals.	18	2	18	2	122[1]
Tetraethyl pyrophosphate (40%)	4 oz.—100 gals.	18	2	18	2	246
" " (100%)	3 oz.—100 gals.	20	0	20	0	238
Check	No spray	0	20	0	20	5

[1] This canvas was small, only about half the size of the others.

grower who was successful in killing the cicadas in a young peach orchard with this spray at the rate of 2 ounces of the material per 100 gallons. The newly emerged cicadas were massed on 2 and 3 year old trees which were drenched with the spray. On larger trees it was later found necessary to increase this dosage to 4 ounces per 100 gallons to get satisfactory kill.

A Licking County apple grower, who had a very severe cicada infestation, was unable to kill them when using 2 ounces of tetraethyl pyrophosphate 40 per cent per 100 gallons when delivered by a speed sprayer. Many cicadas flew away and were not harmed. He then increased the concentration to 4 ounces per 100 gallons and about 90 per cent of the adults dropped from the tree within 20 minutes and died within 24 hours. The migration from outlying woods area and continued emergence from the soil made it necessary to repeat the application at least twice before the brood subsided. Even this expensive program did not prevent some damage from egg-laying.

This grower also tried hexaethyl tetraphosphate 50 per cent at the rate of 1 pint per 100 gallons and secured equally good results, although not complete control. Later this grower and others used tetraethyl pyrophosphate 20 per cent at a strength of 8 ounces per 100 gallons with good success.

A grower in Jefferson County used hexaethyl tetraphosphate 50 per cent twice on his whole orchard and claims to have saved his trees from serious mutilation. He applied the material at night and in the early morning, avoiding spraying during the period from 9 A.M. to 6 P.M.—when the cicadas were too active and flew away from the approaching spray fog. This was the only grower who practiced night spraying.

Results following the use of the phosphate insecticides were made known to the growers through county agents, over the radio, and by telephone, and the word soon spread. The chief difficulty was in delayed delivery of materials. This proved costly to the growers, some of whom did not receive the insecticide until egg-laying was well underway. Too, the need of repeat applications, which in all cases proved necessary, increased the spray cost. Heaviest losses occurred to young trees, particularly those growing near a woods or as replacements in mature orchards. Growers who depended on sprays to protect very young trees should have covered them with cheesecloth in the beginning for the continued migration of cicadas and those which escaped the spray caused too much damage to these young uncovered trees.

The spray had to be applied immediately after being mixed in the tank and directly on the cicadas. Best results were secured with a heavy spray fog which quickly enveloped the tree. Two men operating spray brooms succeeded best with both spraying the same tree, as the high pressure machine passed in order to strike the startled and flying insects. Speed sprayers did very well when slowed down to give adequate coverage.

There was no residual protection afforded by any of these sprays. There was no damage to foliage even when lead arsenate and the mild sulfurs were mixed in the sprays. The addition of lime to the spray rendered it ineffective. The porcelain cylinder linings were damaged by the insecticide in some types of spray machines.

When using tetraethyl pyrophosphate 40 per cent, one operator was made slightly ill and suffered a headache for 2 days. Most operators experienced no disagreeable effects if they avoided the spray fog and sprayed with the wind.

After waging this difficult battle with its highly variable outcome, growers disagree somewhat as to the success of the treatment, but agree that the most hopeful aspect is that the cicadas will not return to *eastern* Ohio until another 17 years have elapsed.

CONCLUSIONS.—Tetraethyl pyrophosphate and hexaethyl tetraphosphate were effective in killing the cicadas. The heavy infestation that existed, continued emergence from the soil, and migration into the treated area made repeat application necessary. Although the effective materials gave up to 90 per cent control, spraying proved costly. Parathion was slow in killing, even at high dosage. DDT, benzene hexachloride, chlordan, chlorinated camphene, and nicotine sulfate were not effective in controlling the periodical cicada.

The Use of Acaricides in Concentrate Form

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At present, the control of mites is the major spray problem in Ohio orchards. This problem is found in all sections of the state, in both large and small plantings, and may be associated with all types of effective spray programs. The most thorough type of spraying with the most effective materials is required for good mite control.

The many advantages inherent in the application of concentrate sprays make it almost a certainty that future years will see a wide use of such sprays. However, this will come about only if concentrates can be so applied as to give good control of diseases, insects, and mites.

Since mite control calls for the best spray practices, experiments with concentrate acaricides were planned and conducted during the past season. If such experiments proved successful, it was considered that a definite step in demonstrating the usefulness of concentrates would be made. Four field tests were conducted in orchards at or near Wooster, Ohio.

Two different concentrate sprayers,[1] both of which may be considered as experimental types, were employed. The principle of each of these machines centers about a large volume air blast into which the finely divided concentrate is introduced by nozzles or other means.

The first test was conducted in a well grown 12-year-old orchard on Grimes and Stayman varieties. Four acaricides—dinitro-o-cyclohexylphenol, dicyclohexylamine salt 20 per cent,[2] Bis (p-chlorophenoxy) methane,[3] Parathion 25 per cent,[4] and alkyl-2-thiazolinyl sulfide[5]—were used. All four materials were applied to the trees by three different methods: first, by the regular high pressure sprayer; second, by a regular air blast sprayer; and third, by the concentrate sprayer. Materials used in this last named rig were concentrated to five times the normal dosage. For example, if summer dinitro was applied normally at 1.25 pounds per 100 gallons of water, in the case of the concentrate only 20 gallons of water was used for the same amount of acaricide. At least three, and sometimes four, single-tree plots were used for each material in each test. The mite population in terms of mites per leaf on each replicate was determined by population counts on five leaves made before spraying and at different intervals of time following the applications.

The summarized data secured for this experiment are presented in table 1.

A study of table 1 indicates that the acaricides applied as concentrates were fully as effective as normal dilutions. The usual discrepancies that occur in field data are to be found in the table, but the results in general are quite favorable for the concentrate sprayer. Careful inspections of the trees made during and following the experiment showed no injury to fruit or foliage on any of the plots.

The second experiment was conducted in the same orchard as the first, but on Red and Golden Delicious varieties. These trees were somewhat smaller than the trees of the first experiment and it is probable that they could have been sprayed thoroughly with 15 gallons of normal dilute spray. The same technique was used in both experiments, but the object of the second was to determine if different high concentrations of the same material would give similar results, other factors being equal. Three materials were each applied at 5 times and 10 times the normally recommended strengths. The materials and results are shown in table 2.

Although the figures in table 2 indicate a trend in favor of the higher (×10) concentration, the differences are not significant. However, there is no doubt as to the effectiveness of the high concentration. Due to the decline of mites on the check trees only one post spray count was made. There was no foliage or fruit injury on these plots.

At the same time and on the same varieties several additional materials were tested at 10 times normal concentrations. These included dinitro-o-cyclohexylphenol, dicyclohexylamine salt[6] 20 per cent, bis (p-chlorophenoxy) methane, and (di-(parachloro-phenyl) methyl carbinol.[7] All

[1] Furnished by F. E. Meyers & Bro. Co., Ashland, Ohio and by The Hardie Mfg. Co., Hudson, Michigan.
[2] DN-111, The Dow Chemical Company.
[3] *Neotran*, The Dow Chemical Company.
[4] *Thio-fos*, American Cyanamid Company.
[5] *IN-4200*, E. I. du Pont de Nemours & Co.
[6] Dry Mix No. 1. Dow Chemical Company.
[7] *Dimite*, Sherwin-Williams Company.

Table 1.—A comparison of three different types of spraying with acaricides.

Material	Type of Sprayer Used	Dilution	Gals. per Tree	Mites per Leaf				
				Pre-spray count	Post-spray counts		Pre-spray count	Post-spray count
				July 21[1]	July 24	July 28	Aug. 2[1]	Aug. 6
Dinitri-o-cyclohexyl-phenol, dicyclohexyl-amine salt 20%	High-pressure	20 oz.—100 gals.	20	11.6	0.5	0.7	2.8	0.2
	Air blast	20 oz.—100 gals.	19	44.9	1.7	4.4	—	—
	Concentrate	20 oz.— 20 gals.	3	4.2	0.0	1.0	7.4	0.2
Bis (p-chlorophenoxy) methane 40%	High pressure	20 oz.—100 gals.	20	18.6	0.5	1.6	7.4	2.0
	Air blast	20 oz.—100 gals.	18	21.4	1.6	5.5	—	—
	Concentrate	20 oz.— 20 gals.	4	24.3	0.3	1.3	2.5	0.3
Parathion 25%	High pressure	5 oz.—100 gals.	20	16.0	0.8	3.2	9.6	1.9
	Air blast	5 oz.—100 gals.	19	20.8	0.3	3.9	—	—
	Concentrate	5 oz.— 20 gals.	4	26.5	0.3	3.6	5.3	0.6
Alkyl-2-thiazolinyl sulfides	High pressure	12 oz.—100 gals.	20	4.9	0.3	0.9	0.5	2.5
	Air blast	12 oz.—100 gals.	18	65.6	15.3	3.9	—	—
	Concentrate	12 oz.— 20 gals.	4	6.6	1.6	0.9	4.5	0.4
Check	DDT Sulfur Spray		—	44.6	18.9	29.5	44.0	16.4

[1] Plots sprayed on July 22 and August 3.

gave good reductions of mite populations and produced no injury except in the case of summer dinitro, where typical burning of leaves resulted. The injury was noticeable on both varieties but did not affect the quality of the crop at harvest.

Experiment 3 was conducted in a 22-year-old orchard at Wooster, Ohio. The trees used included the Baldwin, Stayman, Grimes, and Jonathan varieties. They were well grown and quite large; in fact, they were approximately the same size as mature trees. At least 20, and in some cases 25 or more, gallons of normal spray would be required for thorough coverage. Due to lack of other suitably infested trees in this orchard no direct comparison of results could be made with trees sprayed with a high pressure rig. However, in a near by orchard the same materials were applied with a regular sprayer and a rough comparison may be made. In this latter orchard the trees were older and somewhat larger. The variety was Red Delicious. The results for the two orchards are given in table 3. Note the difference in the quantities of spray applied by the two methods.

This was a severe test for the concentrates as the trees to be covered with the small amount of spray were large. In general, the results appear to favor high pressure spraying but when the large additional amount of spray that was used is considered it is obvious that the concentrates gave a good account of themselves.

Table 2.—Effect of different concentrations on mite populations.

Material[2]	Concentration	Gallons per Tree	Mites per Leaf	
			Pre-spray[1] count Aug. 3	Post-spray count Aug. 6
Alkyl-2-thiazolinyl sulfides	12 oz.—20 gals.	2.8	13.0	1.8
	12 oz.—10 gals.	1.5	18.9	0.8
Parathion 25%	5 oz.—20 gals.	3.0	9.1	0.9
	5 oz.—10 gals.	1.4	45.2	0.2
Dinitro-o-cyclohexylphenol[3] 40%	6 oz.—20 gals.	2.7	44.8	2.6
	6 oz.—10 gals.	1.5	30.6	0.6
Check—DDT & Sulfur	—	—	29.0	7.5

[1] Sprayed August 4.
[2] Due to the fact that only one post-spray count was made, the acaricides involved had no opportunity to demonstrate ovicidal or residual action. Therefore, no comparison between the acaricides used should be made.

Table 3.—Comparison of acaricides in two orchards. Concentrate sprays—B. & E. Orchard, Wooster, Ohio.

Material	Dilution	Gallons per Tree	Mites per Leaf		
			Pre-spray count July 22[1]	Post-spray counts	
				July 26	Aug. 5
Bis (p-chlorophenoxy) methane 40%	20 oz.—20 gals.	4	56.4	4.4	3.7
Dinitro-o-cyclohexylphenol, dicyclohexylamine salt 20%	20 oz.—20 gals.	4	62.6	3.5	0.6
Alkyl-2-thiazolinyl sulfides	12 oz.—20 gals.	4	41.0	7.2	2.5
Parathion 25%	5oz.—20 gals.	4	33.4	1.0	7.3
Check	—	—	36.0	41.4	12.7
High pressure hydraulic sprays—Melrose Orchard, Wooster, Ohio					
			July 19[2]	July 22	
Bis (p-chlorophenoxy) methane 40%	20 oz.—100 gals.	33	15.0	1.9	—
Dinitro-o-cyclohexylphenol, dicyclohexylamine salt 20%	20 oz.—100 gals.	33	9.7	1.7	—
Alkyl-2-thiazolinyl sulfides	12 oz.—100 gals.	33	11.9	1.5	—
Parathion 25%	5 oz.—100 gals.	33	26.2	0.3	—

[1] Sprayed July 23.
[2] Sprayed July 20.

Also, the lower mite populations in the high pressure sprayed orchards must be considered. In fact, when placed on a percentage basis there is relatively little difference in control. In this experiment there was no injury to fruit or foliage.

Experiment 4 was similar to number 3 and was conducted in the same orchard and on the same varieties. Mite populations were somewhat lower than in the first experiment but results were almost identical as far as control was concerned. For this reason the summarized data from the experiment are not given in this paper.

CONCLUSIONS.—Numerous acaricides used at 5 and 10 times normal concentrations gave control of the European red mite equal to that obtained by conventionl spraying with high pressure.

Damage to fruit and foliage was noted in only one instance, and in this case it was no greater than that produced by high pressure spraying.

Although not discussed in the text, savings in time, labor, and materials were indicated by the use of concentrates.

THALLIUM AND ALUMINUM IN BEES

One of the authors (Shaw 1942) has shown that poisons containing either arsenic or thallium are fatal to bees. Although bees were killed by thallous sulfate there was no certainty that they contained thallium or, if so, how much was necessary to kill a bee. To get at these facts 100 bees, killed by thallous sulfate, were digested in sulfuric acid and after removal of the iron and aluminum by sodium hydroxid solution the thallium was precipitated as thallous iodide. It was interesting to note that the iron and aluminum precipitate was nearly all alumina as it had only a reddish tinge indicating a very small amount of iron. Apparently the bee makes use of the lighter aluminum ions in its life process.

The amount of thallous iodide was 10.0 milligrams which makes an amount of .062 milligrams of thallium in each bee. In other words 2 milligrams of thallous sulfate killed 13 bees.

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The Oriental Beetle as a Turf Pest Associated with the Japanese Beetle in New York[1]

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In the area within 20 miles of New York City the populations of scarabaeoid larvae recently found in damaged turf have been highly varied in composition. In many cases the predominant species has been the oriental beetle, *Anomala orientalis* Waterhouse, a fact having an important and complicated relationship with the program for biological control of the Japanese beetle. This paper describes the situation and some steps taken to find means of controlling the combined populations.[2]

Earlier Investigations on Oriental Beetle.—In the middle 1920's when the Japanese beetle, *Popillia japonica* Newman, in its northward spread from New Jersey, had made its appearance in a few localities in and around New York City, workers from the federal Japanese Beetle Laboratory at Moorestown, New Jersey, found that two other scarabaeoid species, presumed to be of Asiatic origin, were already locally established in the area. One of these was *Autoserica castanea* Arrow, now known as the Asiatic garden beetle. The other was *Anomala orientalis* Waterhouse which was at first known as the Asiatic beetle, but since 1933, as the oriental beetle.[3]

Investigations of these species were started on Long Island in 1927 and continued for several years (Hallock 1929, 1930, 1933). At the same time a comprehensive study of the oriental beetle was published in Connecticut by Friend (1929). From these studies it was apparent that the adult oriental beetle is an unusually inconspicuous insect which feeds very little and can pass unnoticed by the public. It was also shown that the larvae were sometimes found in concentrations highly destructive to turf. By 1933 it was apparent that while the Asiatic garden beetle, acting as a minor turf and garden pest, was spreading at least half as rapidly as the Japanese beetle, the oriental beetle was spreading only very slowly. At the close of these studies it was known that turf injury by the oriental beetle and the Asiatic garden beetle could be prevented by applying lead arsenate at the rate of 10 pounds to the 1000 square feet as recommended for Japanese beetle (Fleming 1936).

Factors Linking the Oriental and Japanese Beetles.—By the late 1930's the Japanese beetle had spread over the areas where Hallock had studied the oriental beetle. Since the larvae of the two species are practically indistinguishable to the naked eye, the presence of larval *Anomala orientalis* mixed with larval *Popillia japonica* can pass unnoticed unless the raster of every grub is inspected with a lens. The two species are linked through their common susceptibility to infection with the milky disease organism, *Bacillus popilliae* Dutky (Dutky 1941). As the Japanese beetle became more important economically in New York in the late 1930's the State Experiment Station at Geneva began to cooperate in the distribution of biological agents of control developed at the federal Japanese Beetle Laboratory in New Jersey. Milky disease spore powder was first introduced into southern Westchester County in 1940 and into Nassau County in 1941.

The oriental and Japanese beetles appear to be somewhat alike in their susceptibility to deficiencies of soil moisture. The decline which was observed in the abundance of oriental beetle in the 1929–30 generation, attributed by Hallock to a deficiency of summer rainfall, parallels the decline of the Japanese beetle in New Jersey in the same period, attributed by Hawley (1944) to drying up of the eggs in the soil. A similiar deficiency in moisture prevailed in the summer of 1943 and the Japanese beetle populations of 1944, 1945 and 1946 in the metropolitan New York area were sharply reduced, During these years the lawns and golf courses largely recovered from the grub injury they had acquired after the moister summers of 1941 and 1942. Unfortunately,

[1] Eastern Branch program 1948. Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 791, 1949.

[2] A similar paper is being prepared in regard to larval populations in which the predominant form is *Cyclocephala borealis* Arrow.

[3] The ambiguous term "Asiatic beetle" is to be avoided for either species.

an enthusiastic laity in New York tended to give all the credit prematurely to the milky disease spore powder which had been intensively applied in the 1940 to 1944 period by the state. The public was thus ill-prepared for the general and marked rise in Japanese beetle abundance observed in the summer of 1947, following the fairly moist summer of 1946, and fresh outbreaks of turf damage in the fall of 1947. Since the Japanese beetle, in its double role as a foliage and a turf pest, is both conspicuous and much publicized, it quite naturally tends to get the public blame for injury caused by inconspicuous insects associated with it. In October 1947 the local horticultural inspectors in Westchester County and New York City.[1] received numerous complaints of turf damage in localities where milky disease spore powder had been distributed. One inspector in visiting several such areas, found and recognized *A. orientalis* as the leading cause of the trouble. In the same season the writer, visiting several points around New York City, found mixed square-foot populations of 50 to 75 grubs showing preponderences of *Anomala orientalis*.

The mixed composition of the turf-destroying populations was apparently unknown to the public. In view of the general acceptance of the idea that the fresh injury was due simply to a return of Japanese beetle it was not surprising that some greenkeepers, park managers, home owners, and insecticide dealers, showed an attitude sharply critical of the 10-year old biological control program for that insect. Efforts were made to inform the public of the presence of the oriental beetle species (Adams 1948). It was apparent that in 1948 many lawns and some golf courses containing mixed populations would be treated with chemicals for grub control. In view of the currently high cost of lead arsenate it was suggested that, although the toxicity of DDT to oriental beetle was not definitely known, turf treatments might be tried with that material as recommended for the Japanese beetle.

APPLICATION OF DRY 50 PER CENT DDT ON TURF.—Recommendations current in 1947 in New York for grub-proofing turf against Japanese beetle usually meant, in practice, the application on an acre of 250 pounds of 10 per cent DDT powder in dry form or 50 pounds of 50 per cent wettable DDT powder in a spray. In the spring of 1948 five golf courses in Westchester County, and also some areas in Nassau County, were treated by a third method in which 50 per cent wettable DDT powder was applied dry on the turf. This method involves turf dusting machine.[2] On invitation of Mr. Faulkner and the greenkeepers concerned, the writer made some preliminary observations on the machine and the changes in grub populations following its use.

The machine consisted of a modified crop duster mounted on a small tractor. The dust outlet pipes were fastened into an inverted box-like device attached across the back so that the open underside was held close against the grass. The principle feature was a pair of 3-inch return pipes inserted between the box and the blower intake so that the air and dust inside the machine could circulate instead of merely blowing outward. A long trailing cloth was attached to the rear, In spite of these measures it was observed that on windy days there was some loss of the powder which drifted away in the air. With favorable weather, however, the treatment of a golf course was completed in 2 days. The cost to the golf course was probably well below available estimates for spray application.

At the Century Country Club, White Plains, where the machine operated in the first week of April, 1948, five diggings were made on June 28 at points designated by the greenkeeper as treated. The total yield was: *Anomala orientalis*, 8 larvae, 13 pupae, and 2 soft adults; *Popillia japonica*, 17 larvae, including 10 with advanced milky disease and 1 pupa; *Autoserica castanea*, 3 pupae, 1 adult. At the Ardsley Country Club, June 23, in an area where the writer watched the application on April 19, five scattered square-foot diggings yielded: *P. japonica*, 60 living larvae, about half of them prepupal; *Autoserica*, one larva, three pupae. Some of the *P. japonica* larvae were shrunken as though poisoned and in addition a few dead larvae were found.

[1] Messrs. S. E. Bennett and J. R. Tank of the State Department of Agriculture and Markets.

[2] Pressure Turf Duster, Patent No. 2244987, developed, owned and operated by Mr. F. J. Faulkner of Roslyn, N. Y. Described in principle by Pyenson (1940).

Table 1.—Averages of scarabaeoid populations in single square-foot diggings made in and near a one-half acre plot of turf treated April 27, 1948 with 10 pounds of 50 per cent chlordan[1] applied with a turf duster.

Date of Digging	Treatment Status	No. of Sq. Ft.	Average No. of Living Forms			
			Anomala orientalis	*Autoserica castanea*	*Popillia japonica*	*Cyclocephala*
April 13	Before treatment	2	15.0	5.0	10.5	0.5
May 18	Treated	3	7.7	3.7	11.7	0.0
June 29	Untreated	10	2.1	3.5	9.5	0.3
	Treated	10	1.6	0.3	0.1	0.0
October 5	Untreated	10	12.5	1.6	0.0	0.1
	Treated	10	0.0	0.0	0.0	0.0

[1] *Synklor 50-W.* Naugatuck Chemical Co.

The Ardsley course, unlike the Century golf course and the Westchester Hills course mentioned below, was one on which milky disease spore powder had never been applied and on which the writer did not find symptoms of that disease in *P. japonica* It was, however, the site of a liberation of 100 adult *Tiphia vernalis* Rohwer in 1939. The 60 larvae just mentioned were accompanied by seven attached parasite larvae, two living female parasites, and three empty cocoons characteristic of that species. No trace was found of *A. orientalis.*[1]

Although the DDT applied on these courses had evidently not penetrated the turf in sufficient quantity, by pupation time, to give the degree of control hoped for, abundant moisture in the spring of 1948 evidently helped to avert turf damage in May. A more favorable indication was obtained in October when 3 square feet dug at the Ardsley course, in the same parts of the course as the spring diggings, yielded no larvae, although larvae were found in small to moderate numbers in untreated turf nearby. At Westchester Hills Country Club, White Plains, where the fairways were treated with DDT with the patented duster, about April 30, 3 square feet dug on watered fairways in April and May yielded larvae as follows: *Popillia japonica* 95, *Autoserica* 21, and *Anomala orientalis* 20. Three square feet, dug close to the same points on August 30 and thereafter, yielded no larvae although a light population of larvae was found in a rough nearby in connection with the experiment described below.

EFFECT OF CHLORDAN APPLIED WITH A TURF DUSTER ON A MIXED POPULATION. Chlordan was found effective on Japanese beetle larvae by Fleming (1947) and Schread (1948). On April 27, 1948, at the Westchester Hills Country Club at White Plains the writer secured the cooperation of Mr. Faulkner in the application of 10 pounds of 50-per cent wettable chlordan powder to a half-acre plot on a mowed rough where injury occurred in 1947. The machine was emptied of DDT and the flow rate reduced. The chlordan was applied in about 20 minutes on the dry grass, the duster covering the area twice to secure better distribution. The results are shown in table 1. Diggings on the plot in October were restricted to an area of about 2000 square feet in one corner because only that portion adjoined a check area which had a substantial grub population. The low total population and the absence of *Popillia japonica* in the check may be attributed in part to the drought of the late summer of 1948.

TRIALS OF DDT, CHLORDAN AND PARATHION.—At Kensico Cemetery near Valhalla, N. Y., in a 4-acre turf expanse, located in a section known as "Valhalla Plot," severe turf damage was observed in the fall of 1947. Diggings indicated that *Anomala orientalis* was the only species present in harmful numbers. In the spring of 1948, on one level and less damaged side of the area, five plots, 15 by 66.6 feet were laid out with 12-foot check strips between them. The soil, a sandy loam with a thin turf, was loosened by numerous tun-

[1] Some dead or paralyzed birds, in number less than 20, were reported around three of these golf courses in the month after the treatments. The reports were investigated by the New York State Department of Conservation, Division of Fish and Game, Albany, N. Y.

Table 2.—Averages of scarabaeoid populations in single square-foot diggings made in October 1948 in untreated checks and in turf plots treated May 20, 1948. Kensico Cemetery, Valhalla, N. Y.

Area No.	Treatment on 1000 Square Feet[2]	No. of Sq. Ft.	No. of Living[1]	
			Anomala orientalis	*Autoserica castanea*
Check 1	Untreated	6	11.1	1.0
Plot 1	10% DDT, 6 lbs.[3]	10	0.2	0.0
Check 2	Untreated	6	7.1	1.5
Plot 2	10% DDT, 3 lbs.[3] 5% Chlordan, 2.5 lbs.[4]	10	0.5	0.0
Check 3	Untreated	6	9.0	0.6
Plot 3	5% Chlordan, 5 lbs.[4]	10	0.1	0.0
Check 4	Untreated	6	9.0	2.0
Plot 4	5% Chlordan, 2.5 lbs.[4]	10	0.0	0.0
Check 5	Untreated	6	21.0	7.5
Plot 5	15% Parathion, 10 oz.[5]	10	0.3	1.2

[1] Of 452 larvae, only 10, all found in the checks, were of species other than the two shown.
[2] Quantities for each plot were extended with pyrophyllite, *Pyrax AAB*, to make 10 lbs. of mixture.
[3] From Plant Products Corporation, Blue Point, Long Island.
[4] *Synklor 5-D*, Naugatuck Chemical Co.
[5] American Cyanamid Co.

nels characteristic of moles. On May 20, 1948, the plots were treated as shown in table 2. Of 262 larvae dug in 16 scattered square-foot diggings on and around the plots, just before treatment, 81 per cent were *A. orientalis* and 18 per cent were *Autoserica*. No *Popillia japonica* was found at that time. The chemicals were mixed with pyrophyllite in a barrel-churn mixer and applied dry with a hand-operated fertilizer distributor. The results of diggings made made in and beside the plots in October 1948 are summarized in table 2.

NOTES ON INCIDENCE OF MILKY DISEASE IN ANOMALA ORIENTALIS.—Among the larvae sent to the Experiment Station by Mr. J. R. Tank in the fall of 1947 were some he designated as. *A. orientalis*, milky-diseased; this was confirmed by Dr. Dutky at the Japanese Beetle Laboratory, where the specimens were finally sent. The larvae had been dug at the Mosholu Golf Course in the Bronx. Visiting the course on November 6, 1947, Mr. Tank and the author found some milky-diseased third instars among the larvae of both *A. orientalis* and *Popillia japonica*. Standard milky disease spore powder had been applied by Mr. Tank on this course in 1944.

Of particular interest is the 4-acre turf expanse in the Kensico Cemetery which in 1948 became the site of the five chemical control plots just described. The turf was reported by the management to have been damaged by Japanese beetle larvae in the late 1930's, when that insect was at a peak in much of southern Westchester. Milky disease spore powder was applied by the State Inspector, Mr. Bennett, in 1944. In November, 1947, following the discovery that *Anomala orientalis* was the species currently predominant there, the author assisted Mr. R. T. White of the Moorestown Laboratory in digging about 1500 *A. orientalis* larvae. It was noted that about one larva to the square foot was milky. Milky disease was not noticed in larvae dug there in May, which was to be expected since, in *Popillia japonica*, the disease is not usually evident in New York in May. The disease was found, however, on August 30th and thereafter as shown in table 3. The milky larvae were all first instars. Of the 354 *A. orientalis* dug there in October, 14 were first instars, of which 2 were milky; 152 were second instars, of which 17 were milky; and 188 were third instars, of which none exhibited milky disease symptoms. A similar relation of disease incidence to the stadia of the survivors is commonly found in Japanese beetle larvae.

VARIED DISPERSION OF THE ORIENTAL BEETLE.—The dispersion of the oriental beetle seems to be sharply varied locally. One mile to the west of the heavily infested Kensico Cemetery are the lawns of the Grasslands Hospital and penitentiary. Here has been conducted a field experiment with milky disease on Japanese beetle, started in 1940 as a joint project of the federal Japanese Beetle Laboratory and the State Experiment Station. Numerous diggings have been made in this area by various persons every year but no oriental beetles have been reported, although inspection of every grub with a lens was not practiced prior to 1948. On October 13 1948, 20 scattered square-foot diggings were made on and between the plots; the Oriental beetle continued to be absent from the records (Table 3). One-half mile farther southwest is the Fairview Country Club, one of the golf courses treated with the special turf duster in 1948. The primary species present in 1947 was not determined but diggings made there on untreated turf in October 1948 showed the oriental beetle to be present (Table 3). The writer found turf damage caused by *Anomala orientalis* in 1947 or 1948 at North Tarrytown, Elms-

Table 3.—Composition of larval populations and incidence of milky disease in diggings made in selected places in southern Westchester County, New York, in 1948, after midsummer. Numbers in parenthesis enumerate larvae found exhibiting symptoms of milky disease.

Property and Year of Milky Disease Treatment Within Quarter-Mile	Date of Digging 1948	No. of Sq. Ft.	Living Larvae		
			Anomala orientalis	*Autoserica castanea*	*Popillia japonica*
Kensico Cemetery 1944	Aug. 30	5	76 (3)	18	0
Kensico Cemetery 1944	Oct. 4–13	39[1]	354 (19)	88	4
Winged Foot C.C. 1947	Oct. 6	3	78	19	0
Old Oaks C.C. 1941	Oct. 6	4	1	2	118 (1)
Westchester C.C. 1940	Oct. 6	5[2]	0	1	50 (2)
Fairview C.C. —	Oct. 6	2	6	5	13
Pelham C.C. 1940	Oct. 1	?	231	—	19
Pelham C.C. 1940	Oct. 18	?	105 (2)	—	1
Grasslands Hosp. 1940	Oct. 13	20	0	52	113 (3)

[1] Other species: 3 *Phyllophaga*, 2 *Cyclocephala*, 1 *Macrodactylus*.
[2] Other species: 11 *Cyclocephala*.

ford, and White Plains, so that the Grasslands area was partly ringed about by substantial infestations of oriental beetle. Similar contrasts were found on Long Island in 1948. *A. orientalis* was the principal species in some damaged turf just south of Manhasset yet at the Plandom Gold Course just north of Manhasset, where, between April and October, more than 90 square-foot diggings were made which yielded over 1000 assorted Scarabaeoidea, no *A. orientalis* was found.

Discussion.—Milky disease did not prevent turf damage in the fall of 1947 in certain areas where the Japanese or the oriental, or both species, were present in substantial numbers and spore powder had been applied within a quarter-mile distance several years before. The value of milky disease for Japanese beetle control seems to lie primarily in the cumulative mortality it causes among the larvae, extending over the larval period, and culminating in a marked reduction of the numbers of emerging adult beetles (Adams & Wheeler 1946). With the oriental beetle the number of adult beetles is, in itself, of no economic importance. The desired control of the larvae must have its effect early in the larval period if turf damage in fall is to be averted. Fortunately, the data indicate that oriental beetle larvae can be prevented from developing in turf in the late summer and fall, if chlordan or DDT, at rates suitable for control of the Japanese beetle, have been applied in the spring.

The turf duster mentioned in this paper deserves a more thorough investigation. The apparent lack of control of over-wintering larvae of both species, following applications of wettable DDT with this machine in April, might be due, in part, to losses of DDT during or after application, caused by wind or erosion, or to chemical breakdown of the toxicant after its deposition and before its incorporation into the turf. It should be noted that where this method did seem to give good control (of Japanese beetle larvae, table 1) it was using chlordan at the rate of 20 pounds of 50-per cent powder to the acre, which, according to the data from plot 4, table 2, is double the lower dosage which gave control, by fall, where the chlordan was applied, highly diluted with pyrophyllite, in a fertilizer spreader.

Summary.—Where turf damage caused by scarabaeoid larvae was investigated in New York around New York City in 1947 and 1948, it was found that the larval populations were mixed, the chief components usually being *Anomala orientalis*, *Autoserica castanea*, and *Popillia japonica*. The oriental beetle, although very unevenly distributed, was frequently the predominant species. The public tended to attribute the new turf damage to the Japanese beetle alone and to discredit the program of control with milky disease for that species. Milky disease was found in as many as one in 20 of oriental beetle larvae dug in the fall in areas where milky disease spore powder had been applied several years previously; but the incidence of disease in Japanese and oriental beetle larvae in the fall was insufficient to protect turf from injury by mixed popu-

lations which also included *Autoserica casteanea* and, in a few cases, *Cyclocephala borealis* Arrow.

Chemical control of the oriental beetle was investigated in three ways. On a series of single plots treated May 20, 1948, and examined in the fall, practical control of the oriental beetle was obtained with DDT applied at the rate of about 26 pounds to the acre, with chlordan at 5.4 and 10.8 pounds to the acre and a mixture of DDT at 13 pounds, and chlordan at 5.4 pounds, to the acre. Whether parathion at the rate of 4 pounds to the acre gave a kill in the month following application was not determined, but it was found in October to have provided partial control of the new generation of larvae. In another test a 50-per cent chlordan powder applied dry with a patented turf duster, in April, at a rate to give 10 pounds of toxicant to the acre, on a mixed population, seemed to give practical control of the over-wintering generation of Japanese beetle larvae by late June and full control of the new generation, which consisted largely of oriental beetle larvae, by October. Observations were also made on golf courses reported as treated in April with DDT at the rate of about 50 pounds of 50 per cent powder to the acre, applied dry, with the same patented turf duster. The indications were that the treatment did not give substantial control of the over-wintering generations of either species but that the new generations were controlled in the fall. No special recommendations for chemical control of the oriental beetle in turf, different from those for Japanese beetle, seem necessary at this time.

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DRUG STORE BEETLE INFECTING CALF STARTER PELLETS

As the drug store beetle, *Stegobium paniceum* (Linné) is known to infest nearly all dry plant and animal products it is of interest to note any new man-made products which are attacked. This beetle has previously been of little economic importance while breeding in grain products. Recently a twenty-five pound bag of highly nutritious calf starter pellets was purchased from a feed store and found heavily infested with the drug store beetle. This insect had located a nearly perfect medium in which to carry out its life cycle. Every pellet in this bag was infested. Some pellets had as many as six rounded burrows from which the insect emerged.

All stages of the beetle were present within the pellets as well as two species of Hymenopterous parasites and many active specimens of a mite of the family Cheyletidae. The pearly white beetle eggs were found within the empty burrows. Several generations of the drug store beetle had developed in this bag of pellets which had evidently been held over in a local warehouse for some period of time as many of the beetles had cut exit holes in the cloth. When a cup of these pellets was mixed in skim milk for calf feed at least 200 active beetles would float to the surface. It is quite possible that these active adult drug store beetles might bring about scouring when fed to young calves.

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Parathion for Control of Pests of Ornamental and Flowering Plants

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The excellent contributions of Blauvelt (1948) and Smith (1948) and their coworkers have provided considerable information concerning the use of parathion as a liquefied-gas aerosol, particularly on greenhouse floral crops. Very little information has been made available (Pritchard 1948; Rosenstiel 1948) concerning the use of parathion sprays for control of pests of various ornamental plants.

The use of parathion as a spray has been tested extensively during the past two years in commercial greenhouses and nurseries in the San Francisco Bay region, California. The results obtained and observations made in connection with these tests are here summarized. Limited observations are also included where the growers have used commercial parathion spray materials or liquefied-gas aerosols.

The tests were made against numerous pests and on a wide variety of crops in order to obtain as much information as possible concerning the usefulness of parathion and its limitations on ornamental and other flowering plants. Most of the work has been carried out in greenhouses where elimination of mite and insect pests is particularly desired and where such control often can be accomplished.

Many pests are found to have a contagious distribution, scattered plants having very large populations but most of the crop harboring comparatively few or no individuals. Random sampling is impractical in such instances for accurately evaluating control results, and careful, periodic observations often are found to be of more practical significance.

In some cases, observations for a considerable length of time following treatment of commercial greenhouse plants are not possible, because of the rapid turnover of seasonal potted plants or because of the reluctance of some growers to allow their crops to remain long without insecticidal treatment of some kind. In some cases it is impossible to maintain checks, because entire greenhouses must be treated and neighboring greenhouses contain different crops or lack similar infestations. Nevertheless, many of the tests have been conducted under favorable experimental conditions.

Wettable powder preparations, both 15 per cent and 25 per cent actual parathion,[1] were used. The rate of application was such as to provide as complete coverage of the plants as possible. A wide variety of equipment was used for spray applications, since usually this was furnished by the growers.

Cyclamen mite.—Satisfactory control of the cyclamen mite, *Tarsonemus pallidus* Banks, was obtained on plants which did not provide complete protection for the mites. In the laboratory, 100 per cent control was obtained on African violets with a single application of 0.15 pound actual parathion per 100 gallons of water. Greatest mortality of active stages occurred in 3 or 4 days. Three large greenhouses and a smaller propagating house containing moderate to heavy infestations of this crop were sprayed at a similar rate, and no live mites were found in each case for three weeks following treatment. Scattered pots, however, showed reinfestation within six weeks. A similar experience was obtained following retreatment at twice this dosage.

Several hundred, heavily infested, potted gynuras were sprayed with 0.3 pound actual parathion per 100 gallons of water. Control appeared to be complete at the end of 1 week, but live mites were found on a number of plants 1 month later. A second application was then made of 0.45 pound actual parathion per 100 gallons of water, and the plants subsequently appeared uninfested.

A moderate infestation of the cyclamen mite on 2 dozen fibrous begonias were sprayed at the rate of 0.3 pound actual parathion per 100 gallons of water. Control in this case appeared to be complete, although live mites were found within inspected buds for ten days following treatment.

Thirty potted fuchsias which were heavily infested with the cyclamen mite were sprayed with 0.5 pound actual parathion per 100 gallons of water. The infes-

[1] Furnished by the courtesy of the American Cyanamid Co.

tation returned on one of these plants within three weeks, but the control was otherwise complete.

English ivy, in both greenhouses and lath houses, serves as the primary reservoir of the cyclamen mite in the San Francisco Bay region. Extensive experimental work has been conducted with infestations of these plants. Seven large greenhouses and numerous benches of pots and flats were treated with varying dosages of parathion at various time intervals. The results were variable, and this is attributed mainly to differences in thoroughness of acaricide application, in varieties of ivy infested, in watering practices of the growers, and possibly in temperatures. In some cases, complete elimination of the cyclamen mite appeared to be realized with two applications, 7 or 8 days apart, of 0.5 pound actual parathion per 100 gallons of water. In most cases, however, scattered plants were found to be reinfested within 6 weeks to 3 months following two or three applications at a similar strength with 5 to 14-day intervals. The observations in a single greenhouse, recorded in table 1, are more or less typical.

Very poor control was obtained on Japanese aralia, because of the protection afforded by unfolding leaflets. One hundred small potted plants were sprayed with a dosage of 0.5 pound actual parathion per 100 gallons of water. A number of live mites, representing all stages, were found 6 days later, and they were again abundant on most plants in 19 days.

Table 1.—Cyclamen mite control in greenhouse of English ivy, with use of parathion 25 per cent wettable powder.

DATE	POUNDS PER 100 GALLONS WATER	DAYS SINCE LAST SPRAY	OBSERVATIONS
March 11	2	0	Moderate to heavy infestation over large part of crop.
March 16	2	5	One live ♀ on 50 damaged tips examined.
March 28	—	12	Light infestation on several pots.
March 29	2	13	Light infestation on several pots.
April 5	—	7	No live mites on 50 damaged tips examined.
April 11	—	13	Two adult ♀ ♀, 1 larva on 50 damaged tips.
May 13	—	45	Scattered pots heavily infested.

No apparent control of the cyclamen mite was obtained in azalea buds. Several dozen infested plants which were bedded under lath received four successive applications at 10 to 14-day intervals with concentrations of 0.15 and 0.3 pound actual parathion per 100 gallons of water. Four infested azaleas were treated with dosages ranging up to 1 pound actual parathion per 100 gallons of water.

From 4 to 8 ounces of a spreader[1] were often included with the parathion spray applications for the cyclamen mite. The use of such materials appeared to give a somewhat quicker kill under laboratory conditions and appeared to give more even deposits on many of the plants. No difference in the amount of control was definitely observed, however.

SPIDER MITES.—Control of spider mites, *Tetranychus* spp. was sometimes complete with a single application of a dosage of 0.15 pound actual parathion per 100 gallons of water. This was particularly true where additional spreader was included. In most cases, however, a second application was necessary or else a dosage of 0.25 to 0.3 pound actual parathion per 100 gallons of water. The lower concentration was found not to possess sufficient ovicidal action or sufficient residual action to kill all emerging larvae in these instances.

Complete control of mites was obtained with a single application of 0.15 pound actual parathion per 100 gallons of water on miscellaneous small infestations. These included infested potted plants such as aspidistra, dracaena, datura, gardenia, polygala, scabiosa, and solanum.

In the case of several thousand potted chrysanthemums, most of the plants were lightly infested and complete control appeared to be obtained with a similar dosage. One variety, however, was heavily infested, and there was considerable survival from eggs hatching 1 week after treatment. A second application (0.3 pound actual parathion per 100 gallons of water) after an interval of 2 weeks resulted in complete control on this variety.

Two greenhouses of carnations, heavily infested with spider mites, were sprayed with 0.15 pound actual parathion plus 6 ounces of a spreader per 100 gallons of water. Control appeared to be complete. A few live mites were found in

[1] "Spreader-Sticker," "B-1956," or "Ultrawet."

the corner of one house 5 weeks after treatment, and subsequent spread and build-up were extended over a period of several months. In another infestation on carnations, a bench of potted plants was sprayed with the same dosage but without additional spreader. There was considerable survival from hatching eggs in this case, and a severe infestation returned in a few weeks.

One greenhouse of moderately infested cymbidium orchids was sprayed with 0.15 pound actual parathion per 100 gallons of water. Subsequent examinations during the succeeding 2 months revealed no live mites. The plants then were treated with a higher dosage for scale control and moved to a lath house. A very light reinfestation of mites was found for the first time 7 months after the original treatment. Two other greenhouses of cymbidium orchids were treated with parathion for spider mite control. These received an original application of 0.15 pound actual parathion per 100 gallons of water in March. A few active larvae were found 9 days later; a few protonymphs and deutonymphs were found after 13 days; and scattered adults were found thereafter. The second spraying was made in April, at the end of 4 weeks, the dosage being 0.2 pound actual parathion per 100 gallons of water. A light infestation was again apparent in July, and a third application then was made at the higher concentration. By December, a light infestation had redeveloped.

Two greenhouses of potted hydrangeas were treated with parathion spray at a rate of 0.2 pound actual material per 100 gallons of water. Control appeared to be complete in each case. Two similar greenhouses of hydrangeas which were not treated suffered very severe losses from flower and leaf damage and webbing by the spider mites.

One greenhouse of roses was sprayed with parathion at the rate of 0.25 pound actual material per 100 gallons of water. Control of a severe infestation of the two-spotted spider mite appeared to be 100 per cent.

A light infestation of the spider mite *Tetranychus ludeni* Zacher, on several hundred potted lantanas was treated with 0.15 pound actual parathion per 100 gallons of water. One hundred per cent control was obtained.

A moderate infestation of the spider mite *Septanychus tumidus* (Banks) on a few potted "kentia" and phoenix palms under different conditions and several hundred potted marantas was sprayed with 0.15 pound actual parathion per 100 gallons of water. One hundred per cent control was obtained in each case.

A moderate infestation of the citrus red mite, *Paratetranychus citri* (McG.), on dwarf lemon, elaeagnus, and skimmia nursery stock was sprayed with 0.25 pound actual parathion per 100 gallons of water. The eggs were unaffected and reinfestation occurred within a few weeks although all active and moulting stages were killed.

FALSE SPIDER MITES.—Parathion (as well as tetraethyl pyrophosphate) was ineffective for any of the false spider mites against which it was tested

No control was apparent against moderate to heavy infestations of the privet mite, *Brevipalpus inornatus* (Banks), on several hundred azaleas, both in greenhouses and under lath, as well as several other hosts. Applications were made with concentrations varying up to 0.5 pound actual parathion per 100 gallons of water.

An undescribed species of *Brevipalpus* on several dozen lycaste and catasetum orchids was unaffected by 0.3 pound actual parathion per 100 gallons of water.

Several phalaenopsis orchids which had a severe infestation of the mite *Tenuipalpus pacificus* Baker were sprayed with 0.15 pound actual parathion per 100 gallons of water. No control was evident.

BUD MITES.—A number of camellias with heavy infestations of the bud mite *Aceria camelliae* Keifer were sprayed with 0.38 pound actual parathion per 100 gallons of water. Bud examinations during the following three weeks indicated that no apparent control was obtained.

THRIPS.—Two greenhouses containing severe infestations of the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), were treated with parathion. One house contained azaleas while the other contained azaleas, fuchsias, and miscellaneous plants. One hundred per cent control was obtained in each case with a single application of 0.15 pound actual material per 100 gallons of water.

In a severe infestation of the gladiolus thrips, *Taeniothrips simplex* (Mor.), four 50-foot rows of plants were treated with

light to heavy applications of 1 per cent parathion dust. Observations made 4 and 9 days later indicated that no control had been obtained within the leaf sheaths or flower buds.

APHIDS.—Most of the observations made on aphid control were incidental to tests against other insects at relatively high dosages. Small but severe infestations of the aphid *Cerataphis lataniae* (Boisduval) on potted "kentia" palms and of the ivy aphid, *Aphis hederae* Kltb., on potted English ivy, were sprayed with 0.15 pound actual parathion per 100 gallons of water. One hundred per cent control was obtained in both instances.

WHITEFLIES.—One bench of coleus, heavily infested with the greenhouse whitefly, *Trialeurodes vaporariorum* (Westw.), was sprayed with 0.15 pound actual parathion per 100 gallons of water. One hundred per cent control was obtained.

An exceedingly severe infestation of the same species in a greenhouse of bouvardia was sprayed with 0.13 pound actual parathion per 100 gallons of water. One hundred per cent control was obtained. A similar greenhouse of infested bouvardia, which served as a check, was subsequently treated by the grower with a commercial liquefied-gas aerosol containing 10 per cent parathion. Two applications, four days apart, were made at a rate of 1 pound per 45,000 cubic feet. Only partial adult control and no apparent larval control was obtained with the aerosol treatments.

MEALYBUGS.—Parathion is one of the best materials yet tested against mealybugs. The species which are ovoviviparous and live exposed are easily killed, but the control of those having egg sacs and those hiding beneath leaf sheaths or on the roots presents a more difficult problem.

The long-tailed mealybug, *Pseudococcus adonidum* (L.), was successfully controlled with 0.15 pound actual parathion per 100 gallons of water on small tests with miscellaneous potted plants. In the case of a greenhouse of phalaenopsis orchids which had a heavy infestation and which was sprayed with a similar concentration, the control at first appeared to be complete. A light infestation appeared a few weeks later, however, probably because of incomplete coverage underneath the broad leaves. Several hundred dracaenas as well as miscellaneous plants having heavy infestations were sprayed with a dosage of 0.25 or 0.3 pound actual parathion per 100 gallons of water. One hundred per cent control was obtained in these instances.

Small scale tests with the coconut mealybug, *Pseudococcus nipae* Maskell, on *Philodendron "dubia"* indicated that complete control could be obtained with 0.15 pound actual parathion per 100 gallons of water. Most of these plants, however, were sprayed with twice that dosage, and elimination was accomplished.

A heavy infestation of the citrophilus mealybug, *Pseudococcus gahani* Green, on garden lantanas was thoroughly sprayed, partly with 0.15 pound and partly with 0.3 pound actual parathion per 100 gallons of water. No reinfestation occurred on any of these plants within a year.

A greenhouse containing fuchsias, pelargoniums, and ivy geraniums with a moderate infestation of the grape mealybug, *Pseudococcus maritimus* (Erhorn), was sprayed with parathion at a concentration of 0.15 pound actual material per 100 gallons of water, and then with twice that dosage two weeks later. Complete control was obtained. One greenhouse of Boston ferns, lightly infested with this mealybug, was sprayed with a dosage of 0.25 pound actual parathion per 100 gallons of water. No reinfestation occurred.

Control of the citrus mealybug, *Pseudococcus citri* (Risso), was first tested on two benches of heavily infested coleus. Plants on one bench were thoroughly sprayed with 0.15 pound actual parathion per 100 gallons of water, while twice that dosage was used on the others. Complete control was obtained on all plants. One greenhouse of moderately infested bouvardia was treated with parathion at a concentration of 0.25 pound actual material per 100 gallons of water. Although a few live crawlers were found 3 weeks later, no live mealybugs were found at the end of 6 weeks. One greenhouse of gardenias with a heavy infestation of citrus mealybug was sprayed with a similar dosage. A few live mealybugs were found 3 weeks later, and the plants were then resprayed with a similar dosage. Two months following the second treatment a light reinfestation was evident. A bed of densely matted stephanotis which was heavily infested was also sprayed with parathion at a rate of 0.25 pound actual material per 100 gallons of water, and it was resprayed with the

same dosage 3 weeks later because of the persistence of a few live mealybugs. No live mealybugs were observed on these plants until 3 months after the second treatment.

SOFT SCALES.—The very young stages as well as adults of certain species of soft scales were susceptible to parathion sprays, but the "rubber" stage was found to be more or less resistant.

All of the immature stages of the soft scale, *Coccus hesperidum* L. on several hundred phoenix palm seedlings were killed with an application of 0.5 pound actual parathion per 100 gallons of water. Many of the adults were unaffected, however. A similar experience was obtained with infestations on a large cycad and on a few philodendrons, scheffelaras, and fiddle-leaf figs sprayed with 0.45 pound actual parathion per 100 gallons of water.

The late immature stage of the hemispherical scale, *Saissetia hemisphaerica* (Targ.), on about 100 birds' nest and maidenhair ferns was not killed with 0.3 pound actual parathion per 100 gallons of water. Only adults, crawlers, and eggs were present in a heavy infestation on a large tree fern and monstera which received a similar dosage. Complete control was obtained, although eggs continued hatching for over 2 weeks.

Control appeared to be complete in the case of a light infestation of adults of the cottony scale *Pulvinaria floccifera* Westw. on a few potted camellias which were sprayed with parathion at a concentration of 0.25 pound actual material per 100 gallons of water.

Adults of the soft scale *Coccus pseudohesperidum* (Cockerell) on a few cattleya orchids were sprayed in part with 0.38 and in part with 0.5 pound actual parathion per 100 gallons of water. Three weeks later, the scales sprayed with the heavier concentration were dead while the others appeared alive. Five weeks after treatment, all scales on sprayed plants were dead.

ARMORED SCALES.—Excellent control of armored scales was generally obtained with parathion, although mortality appeared to be very slow.

A heavy infestation of the Florida red scale, *Chrysomphalus aonidum* (L. on several thousand potted "kentia" palms was sprayed with a dosage of 0.3 pound actual parathion per 100 gallons of water. Many larger females appeared alive after 2 weeks, but all were dead after 4 weeks. Similarly, 32 aspidistra plants having a heavy infestation of the scale *C. bifasciculatus* Ferris were sprayed with 0.5 pound actual parathion per 100 gallons of water. All scales were dead in 5 weeks on the plants sprayed.

One hundred per cent control of a light to moderate infestation of the fern scale, *Pinnaspis aspidistrae* (Sign.), was obtained in a greenhouse of Boston ferns which were sprayed with a concentration of 0.3 pound actual parathion per 100 gallons of water. In the case of 1000 pots of heavily infested *Ophiopogon* which were sprayed with 0.5 pound actual parathion per 100 gallons of water, a few females appeared alive 1 month later. These plants were resprayed at that time by the grower with a commercial preparation.

Parathion, at a concentration of 0.2 pound actual material per 100 gallons of water, failed to control a few of the adult females of *Diaspis boisduvalii* Sign. on several cattleya orchids which were heavily infested. All of the exposed scales in a moderate infestation of this species in a greenhouse of cymbidium orchids were killed with a concentration of 0.25 pound actual parathion per 100 gallons of water. Many of the scales beneath the sheaths, however, appeared to be unaffected. Scales also survived which were similarly protected on several cattleya and cymbidium orchids which were sprayed with 0.5 pound actual parathion per 100 gallons of water.

About 100 cypripedium orchids having moderate infestations of the scale *Pseudoparlatoria parlatorioides* (Comst.) and the scale *Parlatoria proteus* (Curtis) were sprayed with 0.38 pound actual parathion per 100 gallons of water. Five weeks later a few adult females of both species appeared alive, but all were dead at the end of 2 months.

Several hundred phoenix palm seedlings having a moderate infestation of the oleander scale, *Aspidiotus hederae* (Vallot), were sprayed with 0.5 pound actual parathion per 100 gallons of water. Complete control was obtained within 2 weeks.

CATERPILLARS.—Parathion gave excellent control of several different lepidopterous pests against which it was tested, except where the caterpillars were boring in terminal plant growth.

Two greenhouses of azaleas having moderate to heavy infestations of the azalea leaf miner, *Gracilaria azaleella* Brants, were sprayed with a single application of 0.15 pound actual parathion per 100 gallons of water. The pest was eliminated in both instances.

A moderate infestation of the orange tortrix, *Argyrotaenia citrana* (Fernald), on two benches of greenhouse azaleas, was sprayed with 0.15 pound actual parathion per 100 gallons of water. One hundred per cent control was obtained. Adults failed to emerge in the laboratory from all pupae obtained on plants which had been sprayed.

Two adjoining greenhouses of carnations, heavily infested with the leaf roller *Platynota stultana* Wals., were sprayed with a single application of parathion at a concentration of 0.15 pound actual material per 100 gallons of water. Counts made following treatment were based on dead and living larvae, the abandoned nests being disregarded. Of these recovered larvae, 66 per cent were dead 3 days after spraying and 60 per cent were dead after 6 days. The live caterpillars were found in flower buds and boring within terminal shoots. The infestation, although comparatively light after spraying, persisted for many months.

CHRYSANTHEMUM GALL MIDGE.—In a severe infestation of the midge *Diarthronomyia chrysanthemi* Ahlberg, 25 potted chrysanthemums were sprayed with 0.15 pound actual parathion per 100 gallons of water and an equal number of plants was sprayed with twice this dosage. No mortality of the larvae and pupae was apparent in either case. Observations were not made on residual action for adult control because adjacent plants were unsprayed or else treated with benzene hexachloride.

PLANT TOLERANCE.—Potted greenhouse plants which are grown for their foliage were, in general, quite tolerant to moderate applications of parathion. Ferns were found to be the most susceptible to injury. One greenhouse of Boston ferns, sprayed with 0.2 pound actual parathion per 100 gallons of water, showed no damage. In another greenhouse of Boston ferns sprayed with 0.3 pound actual parathion per 100 gallons of water, most plants, including tender shoots, were unaffected. Occasional marginal necrosis of leaflets occurred, however, particularly on var. *whitmanii*. Fifty maidenhair ferns sprayed with the same concentration possibly showed a similar leaflet burn. Several dozen bird's nest ferns and several tree ferns and staghorn ferns showed no damage at the same dosage. Several maidenhair ferns were severely burned when sprayed with 0.5 pound actual parathion per 100 gallons of water. One Boston fern which was sprayed with 0.75 pound actual parathion per 100 gallons of water showed severe injury to new growth and marginal and tip necrosis of older leaflets.

A number of greenhouses containing other ornamental foliage plants were sprayed with 0.25 or 0.3 pound actual parathion per 100 gallons of water. These crops included many thousands of plants such as *Selaginella*, *Cycas*, *Podocarpus*, *Araucaria*, *Phoenix*, *Howea*, *Monstera*, *Philodendron*, *Pothos*, *Scindapsus*, *Syngonium*, *Aglaonema*, *Dieffenbachia*, *Spathiphyllum*, *Nephthytis*, and other members of the Araceae, *Asparagus*, *Aspidistra*, *Sansevieria*, *Dracaena*, and other members of the Liliaceae, *Maranta*, *Calathea*, *Peperomia*, *Ficus*, *Fittonia*, *Hedera*, and other members of the Araliaceae, *Acalypha*, *Codiaeum*, *Serissa*, *Coleus*, and *Gynura*. No injury was detected on any of these plants. A large number of palms, dieffenbachia, and philodendron showed no injury from 0.5 pound actual parathion per 100 gallons of water. Ninety monsteras showed no injury from 0.60 pound actual parathion per 100 gallons of water. One or two plants each of *Dracaena*, *Sansevieria*, *Howea*, *Selaginella*, *Bougainvillea*, *Serissa*, *Peperomia*, *Philodendron cordatum*, *Scheffelara*, grape ivy, and English ivy showed no damage from 0.75 pound actual parathion per 100 gallons of water. At the same dosage there was some leaf curl on *Aglaonema*, *Syngonium*, and some leaf drop on *Gynura*, *Pothos*, and *Coleus*.

One small greenhouse containing cacti and other succulents was sprayed with 0.15 pound actual parathion per 100 gallons of water. No damage was apparent on any of the 500 plants treated, 59 genera and 475 species being represented. A few cacti which received twice this dosage were unaffected.

Potted flowering plants were generally tolerant to moderate dosages of parathion. Poinsettias, however, appeared to be susceptible to injury. Several large plants which were sprayed with 0.25 pound ac-

tual parathion per 100 gallons of water showed no effects except for serious spotting of the red bracts. A grower who used 0.15 pound actual parathion per 100 gallons of water in a greenhouse of poinsettias believed lower leaf yellowing and drop during the following several weeks to be due to the treatment. Another greenhouse of poinsettias which was treated by the grower with a commercial product at a rate of 0.15 pound actual parathion per 100 gallons of water suffered severe spotting of the leaves, but no leaf drop. A third greenhouse of poinsettias, in bloom, was treated by a grower with a commercial liquefied-gas aerosol containing 10 per cent parathion at a rate of 1 pound per 45,000 cubic feet. Severe bleaching and distortion of the red bracts occurred as well as considerable leaf drop.

Two greenhouses of potted hydrangeas (prior to blooming) were sprayed with 0.2 pound actual parathion per 100 gallons of water. No injury was apparent in one greenhouse. In the other case, however, the leaves were soft due to forcing, and about 25 plants of one variety (but not all of this variety) had complete leaf drop within several days.

Three greenhouses of African violets showed a slight marginal necrosis of some blossoms when sprayed at a rate of 0.15 pound actual parathion per 100 gallons of water. Severe flower burn resulted when the same plants were later treated with twice this dosage. A few plants treated with 0.5 pound actual parathion per 100 gallons of water showed no foliage injury.

Several thousand potted chrysanthemums showed no injury to 0.15 pound actual parathion per 100 gallons of water, nor was there any damage to 25 plants (several varieties) in bloom which received twice this dosage. Several thousand potted pelargoniums and ivy geranium, many of which were in bloom, showed no injury after being sprayed with 0.3 pound actual parathion per 100 gallons of water.

Twenty potted cyclamen in bloom showed no injury to 0.30 pound actual parathion per 100 gallons of water. Ten primulas sprayed with 0.50 pound actual parathion per 100 gallons of water showed no foliage injury. Several dozen gloxinias showed no damage from 0.25 pound actual parathion per 100 gallons of water. Several hundred small cin-rarias showed no injury after being treated with a commercial preparation by the grower at a concentration of 0.15 pound actual parathion per 100 gallons of water. Six hundred small Easter lilies were not injured by 0.23 pound commercial parathion per 100 gallons when applied by the grower.

Many hundreds of greenhouse and lathhouse azaleas in bloom showed no injury from 0.3 pound actual parathion per 100 gallons of water, but severe blossom burn and loss of green leaves and buds occurred on a few plants within several days after being sprayed with 0.75 and 1.00 pound actual material per 100 gallons of water. About 50 potted fuchsias sprayed with 0.5 pound actual parathion per 100 gallons of water and hundreds of plants sprayed with lighter dosages showed no injury.

With regard to nursery stock, many hundreds of camellias and daphne and a few rhododendrons showed no foliage injury when sprayed with 0.38 pound actual parathion per 100 gallons of water

Orchids appeared to be very tolerant to parathion. One greenhouse of phalaenopsis in bloom as well as many flowering odontoglossum, oncidium and zygopetalum showed no damage from 0.15 pound actual parathion per 100 gallons of water. Two greenhouses of cymbidiums in bloom showed no injury with 0.20 pound actual parathion per 100 gallons of water nor did another greenhouse of cymbidiums in bloom which received 0.25 pound actual parathion per 100 gallons of water. Several cattleyas in bloom showed no injury from the same concentration. About 100 cypripediums showed no injury when treated with 0.38 pound actual parathion per 100 gallons of water. About 50 orchids were sprayed with 0.5 pound actual parathion per 100 gallons of water. These included twelve genera and 23 different species or hybrids and a few flowers of cypripedium and lycaste. No injury to these orchids occurred.

Cut flower crops did not appear to be affected by parathion which was used experimentally as a spray, but considerable difficulty has been experienced by the growers with the use of commercial spray materials or liquefied-gas aerosols. No damage to foliage or blooms was experienced in a greenhouse of gardenias and several smaller tests where parathion was used at a concentration of 0.25 pound actual material per 100 gallons of water.

Considerable leaf drop, including new leaves, has sometimes been experienced by the growers when using commercial parathion at a rate of 0.15 pound actual material per 100 gallons of water or the 10 per cent liquefied-gas aerosol at approximately 1 pound per 50,000 cu. ft.

Expected leaf drop was apparent in one greenhouse of roses, being dried prior to pruning, when it was sprayed with 0.25 pound actual parathion per 100 gallons of water. Another bed of the same variety but in full flower production showed no injury from the same concentration. Considerable leaf drop has usually been experienced by the growers following treatment with a 10 per cent liquefied-gas aerosol at an approximate rate of 1 pound per 50,000 cu. ft. Sulfur fumigation was not carried out within 1 week before and after their insecticidal treatment.

One greenhouse of bouvardia in bloom showed no injury after being sprayed with 0.25 pound actual parathion per 100 gallons of water. Nor was there injury to a bed of stephanotis in production which was sprayed twice with a similar dosage. One greenhouse of stephanotis, however, which was sprayed by the grower with commercial parathion at a rate of 0.23 pound actual material per 100 gallons showed serious leaf drop and chlorotic leaf spotting.

Two greenhouses of carnations which were sprayed with 0.15 pound actual parathion per 100 gallons of water showed no injury. A few treatments of this crop which have been made by growers with the liquefied-gas aerosols have resulted in no injury.

DANGER TO MAN.—Parathion is a poisonous material and must be handled with care. The writers have not been aware of any adverse effects concomitant with any of their experimental work with parathion. No special precautions were taken except to wash hands after spraying and to change soaked clothing as soon as possible. Respirators were not used, but inhalation of spray mist was avoided as much as possible. Several growers have experienced temporary nausea, headache, and other illness when considerable spraying was undertaken with commercial materials, but the same operators suffered no noticeable effects when employing a respirator while spraying. Growers using the liquefied-gas aerosols have used approved gas masks with canisters designed for organic vapors, and they have experienced no ill effects. Parathion odors in a greenhouse were dispelled within 24 hours after application, and no human reaction to residues has been observed by workers in connection with crops treated by spraying or liquefied-gas aerosols.

SUMMARY.—Extensive experimental work with commercial crops of ornamental and other flowering plants have shown that parathion sprays are very effective for the control of the cyclamen mite, spider mites, thrips, aphids, whiteflies, mealybugs, armored scales, lepidopterous insects and certain stages of soft scales when occurring under relatively exposed conditions. The sprays were ineffective against false spider mites and many mites and insects which were protected by plant tissue.

Plants of a very wide variety were found to be tolerant to insecticidal concentrations of the parathion wettable powder which was furnished for experimental purposes. Ferns, poinsettias, and African violet blossoms were the most sensitive to injury. Roses, gardenias, and stephanotis have often suffered leaf drop as a result of applications of several different commercial spray materials or liquefied-gas aerosols by growers.

No adverse effects to the operator have been noted when a respirator was worn and other reasonable precautions were taken during application of parathion sprays nor to employees working with crops that had been treated.

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The Triethanolamine Salt of Dinitro-o-sec-butylphenol to Control Certain Pests on Fruit Trees

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During the last seven years (1942 to 1948 inclusive) numerous field tests have been made to control certain orchard insect pests with sprays containing the triethanolamine salt of dinitro-o-sec-butylphenol. The composition of this material used was an aqueous solution which contains 8 ounces of the parent phenol equivalent, dinitro-o-sec-butylphenol, per quart.[1] For the sake of brevity this solution will be referred to as "The DN compound" in this discussion.

This material is a clear solution at ordinary temperatures. If subjected to freezing it may be restored to its liquid state by gentle heating and agitation, with no apparent change in chemical or toxicological properties. Alcohol solutions and wettable powders containing the chemical have been tested. While these compositions, at equal toxicant levels, have given control of all species similar to the aqueous solution they are still considered to be in the experimental stage of development. Hence only results with the aqueous solution will be discussed here.

Tests in Michigan include the use of this DN compound in high pressure commercial spraying equipment. The sprays were applied primarily as dormant treatments to control insects and mites on apples, pears, sweet and sour cherries, plums and prunes (except Japanese varieties) and currants; to control leaf curl *Taphrina deformans* (Fcl.) Tul. and green peach aphid *Myzus persicae* (Sulz.) on peaches; anthracnose, *Plectodiscella veneta* (Speg.) Burk., on black raspberries. Sprays containing this DN compound have also been used as green-tip treatments to control pear psylla *Psyllia pyricola* Foerst. on pears; as in-bloom treatments to chemically thin crops on apples, pears, and peaches; and as summer treatments to control foliage infestations of the European red mite, *Paratetranychus pilosus* (C & F), on apples. All results in this report are based on orchard tests involving numerous individual plants for each treatment. Treatments have heen made with the material alone in water and in spray oil emulsions.

Water Sprays.—The DN compound is readily miscible with all spray water encountered in tests in Michigan. The pH of this water includes a range of 6.1 to 8.0. No attempt has been made to determine the total solids in the water.

Aphids.—As dormant treatments, the composition alone in water has been tested extensively against rosy apple aphid, *Anuraphis roseus* Baker, black cherry aphid, *Myzus cerasi* (F), and mealy plum aphid, *Hyalopterus arundinis* (F). Results obtained in spring dormant spray tests to control these species are summarized in table 1.

In addition to the spring dormant treatments shown in table 1, late fall or early winter dormant treatments were applied to apple trees in which this insecticide was used at 1 and 2 quarts in water to make 100 gallons. Rosy apple aphid was controlled with sprays of both dilutions.

From results of fall and spring treatments on apples and spring treatments on plums, prunes and cherries it appears that 1 quart is sufficient to control the three aphid species named above. There was no injury to the fruit trees from the treatments discussed.

Several tests were made with sprays containing 1 and 2 quarts in water to make 100 gallons, for control of currant aphid *Capitophorus ribis* (L). Infestations in the untreated plots were generally light and not uniform, but since none developed in the treated plots the indications are that good control of aphids may be expected from 1 quart on currants. No injury resulted to the plants from these treatments which were applied during the spring-dormant period.

Tests to control green peach aphid, *Myzus persicae* (Sulz.), on peach resulted in severe injury to terminal wood and fruit buds. Since as little as 1 pint in 100 gallons was injurious under Michigan conditions, dormant treatments with this material have been discontinued on peach trees.

Scale Insects.—This DN compound

[1] This composition is available commercially as DN-289.

in water has been tested on apple against overwintering forms of San José scale, *Aspidiotus perniciosus* Comst., scurfy scale, *Chionaspis furfura* (Fitch), and oystershell scale, *Lepidosaphes ulmi* (L). A summary of results is presented in table 2. A few tests were conducted for the control of San José scale on currants. Accumulated data show 2 quarts in 100 gallons effective against this pest on currants also.

It appears that in most instances a dilution of 2 quarts in 100 gallons is sufficient to control these three species of scale insects. Three quarts may be advisable for extremely heavy infestations, but 4 quarts does not appear to be sufficiently more effective than 3 quarts to warrant use of that amount.

No injury to the plants resulted from the dilutions discussed.

PEAR PSYLLA.—Original treatments against pear psylla were applied as spring-dormant pre-oviposition sprays. Where the material was used at 2 quarts such treatments had an efficiency of 85 to 90 per cent. It was observed that adults actually contacted with the sprays were killed. However, during the period of spring-dormant treatment, unless there has been a warm period of several days prior to treatment and unless a temperature of 65° F. or above prevails during treatment, many adults will be under bark scales and in other inaccessible places. Dry deposits of this material apparently have relatively little toxicity to psylla adults. Treatments applied when adult emergence from overwintering is complete, and when oviposition has progressed considerably, are very effective against this pest. However, if such treatments are delayed beyond the green-tip stage some permanent injury to the buds may occur. A so-called green-tip application has been found both effective and safe. A summary of tests applied at this time is presented in table 3.

Table 1.—Results of spring-dormant spray tests to control aphids on apple, cherry, plum and prune.

Amount of Composition in 100 Gal.	Species	Number of Tests	Percentage Control	
			Range	Average
1 pt.	*Anuraphis roseus*	6	69.0–100	91.0
	Myzus cerasi	1	98.2	98.2
1.5 pt.	*Anuraphis roseus*	12	92.0–100	97.0
1 qt.	*Anuraphis roseus*	15	93.0–100	99.9
	Myzus cerasi	6	97.0–100	99.4
	Hyalopterus arundinsis	2	96.5–100	98.2
3 pt.	*Anuraphis roseus*	3	97.0–100	99.1
	Myzus cerasi	6	98.0–100	99.6
2 qt.	*Anuraphis roseus*	7	96.0–100	99.4
	Myzus cerasi	3	99.9–100	99.9
	Hyalopterus arundinsis	1	100	100

Table 2.—Results of spring-dormant spray tests to control scale insects on apple.

Amount of Composition in 100 Gal.	Species	Number of Tests	Percentage Control	
			Range	Average
1.5 pt.	*Aspidiotus perniciosus*	1	96.0	96.0
	Chionaspis furfura	2	90.0– 97.0	93.5
1 qt.	*Aspidiotus perniciosus*	7	86.0–100	94.5
	Chionaspis furfura	4	93.0– 99.0	96.0
2 qt.	*Aspidiotus perniciosus*	5	90.0–100	97.4
	Chionaspis furfura	4	96.0– 99.8	98.3
	Lepidiosaphes ulmi	3	73.0–100	90.0
3 qt.	*Aspidiotus perniciosus*	2	100	100
	Chionaspis furfura	4	97.0–100	98.7
	Lepidiosaphes ulmi	1	96.0	96.0
4 qt.	*Aspidiotus perniciosus*	1	99.7	99.7
	Chionaspis furfura	2	99.0	99.0
	Lepidiosaphes ulmi	5	97.0–100	99.1

Eye-spotted budmoth and cherry casebearer. Spring dormant treatments with the DN compound have been very effective against the immature larvae of the eye-spotted budmoth, *Spilonota ocellana* (D. & S.), and cherry casebearer, *Coleophora pruniella* Clem., as shown in table 4.

Two quarts in water to make 100 gallons appears to be adequate to control these two insects. There was no injury to several varieties of apple and sweet cherry trees nor to Montmorency sour cherry trees.

European red mite. During the course of early investigation with this composition for the control of insects, it was observed that commercially injurious foliage populations of European red mite were appreciably delayed, or prevented entirely, following the use of certain dilutions of this

Table 3.—Results of green-tip spray tests to control *Psyllia pyricola* Foerst.

Amount of Composition in 100 Gal.	Number of Tests	Percentage Control	
		Range	Average
1 qt.	5	98.0–100	99.1
3 pt.	2	99.8–100	99.9
2 qt.	7	99.2–100	99.7
3 qt.	4	98.2–100	99.4

Table 4.—Results of spring-dormant spray tests to control eye-spotted budmoth and cherry casebearer.

Amount of Composition in 100 Gal.	Species	Number of Tests	Percentage Control	
			Range	Average
1 qt.	*Spilonota ocellana*	2	95.5–97.4	96.4
	Coleophora pruniella	1	100	100
3 pts.	*Spilonata ocellana*	3	96.5–98.0	97.2
	Coleophora pruniella	1	99.9	99.9
2 qt.	*Spilonata ocellana*	4	97.0–100	98.4
	Coleophora pruniella	2	99.8–100	99.9
3 qt.	*Spilonota ocellana*	1	99.4	99.4
	Coleophora pruniella	1	99.5	99.5
4 qt.	*Coleophora pruniella*	1	99.5	99.5

Table 5.—Results of spring-dormant spray tests to control European red mite on apples, plums, and prunes.

Amount of Composition in 100 gal.	Number of Tests	Percentage Control About mid-July	
		Range	Average
1 qt.	3	48.5–96.0	77.0
3 pt.	1	98.8	98.8
2 qt.	10	81.7–97.0	90.5
3 qt.	2	92.3–98.0	95.0
4 qt.	2	96.9–99.0	97.9

material in spring dormant treatments. More recently numerous tests have been directed specifically against the overwintering eggs of this mite on apples, plums and prunes. A summary of results appears in table 5.

When applied as strictly dormant treatments there was no injury to apple buds at the dilutions indicated. While 2 quarts in 100 gallons was safe on plums and prunes, some buds were weakened or killed when greater amounts were used. Japanese varieties were not included in these tests.

In tests to control foliage infestations of the European red mite, the composition at 1 pint per 100 gallons gave good control but leaf injury was severe. Attempts to avoid injury by reducing the amount of chemical resulted in poor control.

THE DN COMPOUND WITH OIL EMULSIONS.—Extensive investigations have been made with combinations of oil and this triethanolamine salt of dinitro-o-sec-butylphenol with the objective of developing a safer more generally effective and economical treatment for dormant use than is the case where either of the above insecticides is used alone. In one series of tests various amounts (0.45, 0.57, 0.83, 1.12 per cent by weight) of this dinitro compound were dissolved in oils representing the paraffinic and naphthenic types. These solutions were then applied as 1, 2 and 3 per cent oil emulsions. In other tests, oil emulsions were prepared in the spray tank by use of proprietary emulsible preparations or by use of tank-mix method and then the DN compound was added in various quantities (8 fl. oz. to 2 quarts per 100 gallons) to various dilutions (0.25 to 3 per cent) of the oil emulsion. Here again both the paraffinic and naphthenic types of oils were used.

Without going into details of the tests, it will suffice to note that almost invariably injury to dormant buds resulted from the use of any amount of this dinitro compound in 1, 2, and 3 per cent of oil emulsions. The results of these tests did not show any appreciable difference in the performance of the two types of oils.

In the spring dormant treatments, sprays containing 0.5 per cent oil plus 0.5 per cent of the DN compound have usually caused light to moderate injury to buds on plum, prune, cherry, apple and pear trees. A spray containing 0.5 per cent oil plus 0.25 per cent of this composition has sometimes caused slight injury to plum and prune buds, but has been generally safe to cherry, apple and pear buds. Sprays containing 0.25 per cent oil plus 0.25 or 0.5 per cent of the DN compound have been generally safe to buds on all the above named fruit trees.

At present, data on the safe combinations of oil and this dinitro material are not sufficient to permit definite conclusions regarding control. However, indications are that in case of scale insects and European red mite eggs such combinations will give slightly better control than dinitro compounds alone in water.

Since early experience with triethanolamine salt of dinitro-o-sec-butylphenol with oil indicated definite limitations in such usage, an effort was made to determine some of the limitations in the use of these materials applied separarely. In this connection a very pertinent question is: "How soon after an application of this DN compound may one apply an oil emulsion spray containing 2 per cent or

more actual oil?" Without going into details of experimental procedure and results it may be stated that 3 per cent oil emulsions have been applied with safety to apple buds 2 weeks after the dinitro treatment or at any time after the dinitro treatment following 0.50 inch or more of rain. It is assumed that where a two-spray schedule is used the dinitro compound would be applied first.

SUMMARY.—Numerous tests have been conducted in Michigan orchards to control various insects and the European red mite with dormant sprays containing an aqueous solution of the triethanolamine salt of dinitro-o-sec-butylphenol. This composition contains 8 ounces of the parent phenol equivalent, dinitro-o-sec-butylphenol, per quart. When applied in the spring-dormant period and used alone at 1 quart in water to make 100 gallons of spray it gave good control of rosy apple aphid, black cherrry aphid, mealy plum aphid and currant aphid. Two quarts per 100 gallons gave good control of eye-spotted budmouth, cherry casebearer, San José scale, and moderate infestations of Scurfy and oystershell scales. Control of severe infestations of the latter two scale insects may require 3 quarts. It was effective against pear psylla when used at 2 quarts per 100 gallons and applied in the green-tip stage of bud development. A high percentage of kill of European red mite eggs was obtained with 2, 3, and 4 quarts per 100 gallons of spray applied during the spring-dormant period. Dormant peach buds and terminal wood were severely injured by spring-dormant sprays containing as little as 1 pint of the dinitro composition in water to make 100 gallons. Moderate to severe injury of buds on apple, plum and prune trees resulted from spring-dormant sprays containing from 1 to 3 per cent of oil plus any amount of triethanolamine salt of dinitro-o-sec-butylphenol. However, 0.5 and 0.25 per cent oil emulsions in combination with certain amounts of this dinitro compound offer some promise of practicality and further investigations should be made.

Residual Activity of Insecticides in Control of Turf Insects

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For many years lead arsenate has been used successfully for control of Japanese beetle grubs. Although slow in initial kill it is dependable in ridding soil of nocuous grub populations. Under most conditions its residual activity may be relied upon for 4 or 5 years and occasionally longer. With the advent of DDT, however, it was shown by Fleming & Mains (1947) that the new insecticide was not only much faster in action than lead arsenate when applied to Japanese beetle grub infested soil but was likewise effective for several years.

A report on extensive experiments in the field of turf insects and their control by recently developed insecticides in 1947 (Schread 1948) disclosed the value of five toxicants for control of Japanese beetle grubs, ants and chinch bugs. The residual activity of the insecticides was checked carefully during the summer and autumn of 1948. As a result it was seen that with one exception all showed promise of retaining toxicity in turf and soil for several years or longer.

Turf infested with Japanese beetle grubs was treated with 10 per cent DDT dust at the rate of 250 pounds to the acre on May 15, 1946. The treatment was still effective in the autumn of 1948, constituting actual control of four successive grub populations with one application of insecticide. Only an occasional grub was found in the treated plot on Noveember 5, whereas in the adjacent untreated areas there appeared to be an average of 14.5 per square foot of sod. Earlier in the fall, September 3, a population count revealed an average of 10.5 eggs and one first instar per square foot in the treated plot and 11 eggs, 3 firsts and 8 second instars in the untreated areas. Owing to delay emergence of beetles in 1948 and hot dry weather from early August to mid-October heavy egg populations were not uncommon in September.

In May, 1947, toxaphene was used for control of Japanese beetle grubs as a 10 per cent dust at the rate of 8, 12, 16, 20 and 24 pounds of actual toxicant per acre. All dosage levels gave satisfactory con-

Table 1. Residual activity of chlordan.

1947 Date of Treatment	Actual Chlordan per Acre	Aug. 19, 1948		Sept. 3, 1948		Sept. 25, 1948	
		Grubs	Eggs	Grubs	Eggs	Grubs	Eggs
		per sq. ft.		per sq. ft.		per sq. ft.	
May 20	8 lbs.	0.5	0.5	0.0	18	0.0	0.0
May 20	16 lbs.	0.0	1.5	0.0	9	0.0	0.4
May 20	24 lbs.	0.5	0.5	0.0	11	0.0	0.8
Aug. 13	10 lbs.	0.0	1.1	0.0	10.8	0.0	0.2
Untreated		30.3	8.7	37.5	9	35.0	1.0

Data represent the average of 5 diggings per 0.125 acre plot.

trol, preventing maximum injury before summer. By late autumn, mortality of the population developed during the preceding summer months was virtually 100 per cent in all treatments, whereas in untreated areas grubs averaged 81.5 per square foot. On October 28, 1948, an examination of the plots disclosed an absence of grubs at the 20- and 24-pound levels. At the 16-pound level there was an average of 0.2 of a grub per square foot of turf giving control in the order of 97.7 per cent. Due to an average population of 3.0 grubs per square foot of sod at the 12-pound level control dropped down to 74.5 per cent. At the lowest or 8-pound level there was an average of 3.2 grubs per square foot or control in the order of 73.3 per cent. In the untreated plots the grub population averaged 11 per square foot with a high of 14 and a low of 6. The results attained at the two highest levels of toxaphene compare favorably with DDT in residual action over a period of 18 months.

On May 15, 1947, a 50 per cent wettable benzene hexachloride powder containing 6 per cent gamma isomer was applied to Japanese beetle grub populations at five actual gamma isomer levels of 0.96, 1.92, 2.88, 3.84 and 4.80 pounds per acre. By June 15 control of the infestations was sufficient, especially at the two highest dosage levels, to prevent serious grub injury to the turf. On September 25, grubs averaged from 0.2 to 5.0 per square foot in the five plots. At the same time, however, there were grubs in excess of 80 per square foot in the untreated plots. Examination of the plots on October 28, 1948, when the third Japanese beetle grub population since the insecticide was applied was current, revealed 100 per cent control of the populations at the three highest gamma isomer levels, 79.7 per cent mortality at the fourth level and 75.3 per cent at the fifth or lowest level. In the checks the grub population ranged from 10 to 20 per square foot with an average of 13.7.

Chlordan was applied to excessive Japanese beetle grub populations in turf on May 20, 1947 at 8, 16 and 24 pound levels of actual toxicant per acre. On August 13 of the same year the insecticide was used at a 10-pound level. The results of the experiments were outstandingly successful. In 4 weeks, that is by June 19, the first three toxicant levels had reduced grub populations 88.0, 93.6 and 98.7 per cent from an average of 91.9 grubs per square foot. The August treatment provided control in the order of 93.2 per cent in 14 days. By late September plot examinations disclosed complete absence of grubs at the four dosage levels. Concurrently there was a grub range of from 71 to 117 per square foot in nearby untreated turf. The experimental plots were examined three times during the 1948 season for information relative to the residual action of chlordan for grub control. Results are tabulated in table 1.

It appears from information available that chlordan at all dosage levels studied was very effective in ridding turf of three successive Japanese beetle grub generations. During August, 1948, at a time when egg population was increasing rapidly, there was less than one grub (first instar) average per square foot of turf in the experimental plots in contrast to more than 30 per square foot in untreated areas. Throughout the balance of the season no grubs were found in the chlordan plots; however, eggs appeared regularly in considerable numbers. It would appear that the toxicant did not inhibit egg laying but did destroy the grubs as rapidly as they hatched.

Parathion[1] was applied to grub-infested

[1] *Thiophos*, American Cyanamid Co.

turf in 1947 at three dosage levels. The first series of treatments were made on August 22 and the second series on September 17. One quarter, 1 and 2 per cent dusts were used at the rate of 1, 4, and 8 pounds of technical toxicant per acre. Mortality was rapid in all cases, providing control in 2 weeks and grub extermination within 6 weeks.

The residual activity of parathion is comparatively short lived. Turf samples tested at 2-week intervals showed rapid loss of toxicity. Degeneration of the insecticide in turf appeared to be more rapid in August at high temperatures than in Autumn at comparatively lower temperatures.

On March 23, 1948, composite turf samples were taken from the plots treated with the three toxicant levels of parathion and submitted to the research laboratory of the American Cyanamid Company for assay to determine the residual value of insecticide 6 to 7 months subsequent to its application. The results of the tests showed that in the upper inch of turf treated August 22, 1947, there remained only 0.6 part per million parathion, whereas in the samples taken from the September 17 treated plots there persisted 1.0 part per million parathion. Although there was a month's difference between the first and second series of treatments in 1947, the fact that there were nearly twice the number of parts per million in the September plots the following March than in the August plots may be explained by the existence of cooler air and soil at the time of the fall treatments.

Grub population counts were made in all six parathion plots on October 20, 1948, the results of which appear to table 2.

No significant control was attained at any dosage level in the two series of experiments. The average number of grubs per square foot of turf in the treated plots was virtually the same as in the untreated.

Table 2. 1947 parathion plots examined October 20, 1948.

DATE OF TREATMENT 1947	0.25% PLOT GRUBS PER SQ. FT.	1% PLOT GRUBS PER SQ. FT.	2% PLOT GRUBS PER SQ. FT.
Aug. 22	22.5	17.5	13.0
Sept. 17	16.0	12.0	18.0
Untreated	17.0	22.0	16.5

Data represent the average of 5 diggings per 0.125 acre plot.

From 14 to 30 months have elapsed since the five insecticides discussed were applied to turf composed largely of the basic lawn grasses—Kentucky bluegrass, bents and fescues. At no time immediately following their use nor since has the turf revealed the slightest signs of injury by the toxicants. As a matter of record some of the materials enhanced temporarily the vigor and color of the grass. Just exactly what the reason for this phenomenon may be has not been definitely determined.

Obviously it is important to know the highest dosage level at which the insecticides may be safely used on turf so as to avoid phytotoxicity. Owing to the fact chlordan has been used at more dosage levels than the other insecticides, not only in the case of Japanese beetle investigations but also for control of ants, chinch bug, sod webworms and cutworms without turf injury, it seemed desirable to increase the dosage levels experimentally until the basic lawn grasses were actually harmed. The toxic range between 8 and 50 pounds of actual chlordan per acre has, to date, shown no injury to turf under experimental conditions. Consequently a series of plots was established using the insecticide at 1, 5, 70, 100, 125 and 150 pounds of technical chlordan per acre. The treatments were applied between June 2 and July 12 to turf areas all of which comprised Kentucky bluegrass, Chewing's fescue, Colonial and velvet bends, redtop, dandelion, narrow and broad leaf plantain, chickweed, crabgrass, white clover and fleabane. It was estimated that over 50 per cent of the sod was composed of white clover with 20 per cent bluegrass, 10 per cent fescue and occasional small to larger patches of bents.

By the eighth day following use of the toxicant at 70 and 100 pound levels on June 2, superficial injury to clover, estimated to be about 75 per cent, was obvious. No other species of plants in the plots was affected. The clover recovered completely in 3 weeks.

At the 125 and 150 pound levels applied July 12 white clover was very seriously burned within 4 days. The injury was somewhat more prominent at the higher of the two levels. So far as could be determined bluegrass, fescue, redtop and weeds were not injured; however, velvet

Table 3. 1948 experiments: comparison of insecticides for Japanese beetle grub control.

Toxicant and Date of Treatment	Actual Toxicant per Acre	Original Grubs per Sq. Ft.	Reduction and Grubs per Sq. Ft.		Length of Time Required		Grubs per Sq. Ft.	Reduction
					Weeks	Days		
Toxaphene May 18	24 lbs.	38.6	3.0	92.2%	4	3	Oct. 27 0.0	Oct. 27[1] 100%
DDT May 15	24 lbs.	25.0	9.5	62.0	6	0	Nov. 8 4.2	Nov. 8[2] 78.4
Parathion May	4 lbs.	50.0	5.5	89.0	1	3	Oct. 27 1.2	Oct. 27[3] 95.0
	8 lbs.	50.0	2.0	96.0	1	3	0.5	96.6

Data represent the average of 5 diggings per 0.125 acre plot.
[1] Checks 13.3 grubs per sq. ft.
[2] Checks 31 grubs per sq. ft.
[3] Checks 14.3 grubs per sq. ft.

bent was badly burned and Colonial bent less seriously so. Eight days subsequent to the treatment injured clover and bent grasses showed obvious signs of recovering. By the twelfth day 90 per cent of the clover had regained a normal appearance. Injured bent grasses were much slower in getting back to normal.

Examination of the plots on July 27, 15 days after treatments, revealed complete recovery of both clover and bent grasses. A survey made on November 5, at the time the turf was examined for Japanese beetle grubs, showed all species of grasses and weeds in the six chlordan plots to be in excellent condition. No grubs were found in the treated plots whereas in adjacent untreated turf grub counts averaged 14.1 per square foot with a high of 42 and a low of zero. There was also about one egg average per square foot in the controls but none in the treatments.

It has been reported (Schread 1948) that toxaphene at 16 and 24 pounds of actual toxicant per acre gave somewhat better kill of Japanese beetle grubs during the first season than DDT. These results were further substantiated by additional experiments conducted during 1948. Table 3 gives the results of the tests including parathion for comparison.

Obviously toxaphene is superior to DDT at comparable dosage levels when applied to over-wintering Japanese beetle grub populations. Furthermore a significantly poorer kill of grubs of the succeeding generation was obtained with DDT than with toxaphene. In mid-Autumn no grubs could be found in the plots treated with the latter insecticide whereas in the DDT plots an average of 4.2 grubs per square foot of turf was current.

Repeating an already established performance, parathion at low dosage levels, table 3, provided quick kill of all Japanese beetle grub populations to which the toxicant was applied in mid-May and retained sufficient toxicity to destroy virtually all grubs of the succeeding generation developing in the treated turf during the summer and early autumn. Samples taken from the plots on November 4 showed 0.2 part per million parathion present in the first inch of turf for the treatment applied at the rate of 4 pounds of actual toxicant per acre and 0.6 part per million for the 8-pound level. Presumably the residues were higher two to three months earlier, that is in August and September, when the grub population was developing. In any case, however, the high degree of mortality attained during late summer was revealed when the survey was made October 27 (Table 3).

Control of excessive cornfield ant[1] populations in bent turf by using chlordan at various dosages in 1947 (Schread 1948) prompted a thorough checking of the treated golf course greens in 1948 to determine the residual activity of the toxicant in preventing re-establishment of the species during the latter season. It was seen that no reinfestations occurred on the 13 greens treated in 1947 until June 25, 1948, and then a total of only six colonies were found. Normally, craters surmounting ant colonies commence to appear in late April and early May.

On June 28 series of treatments containing soil fungicides and chlordan were applied to the greens for the two-fold purpose of controlling ants and fungus dis-

[1] *Lasius niger* var. *americanus* Emery

eases. Combination treatments using chlordan 50 per cent wettable powder at the rate of 2 ounces per 1000 square feet with a fungicide at a 3 ounce level were applied to the greens. In all, eight[2] commonly used fungicides were combined separately with the insecticide. Complete disappearance of ant colonies followed and injury to the turf by fungus diseases was prevented. Insecticidal effectiveness continued for a period of 2 to 4 weeks with only an occasional ant colony on any treated green. A schedule was established using the insecticide with a fungicide at 3-week intervals. The practice kept the greens entirely free from ants for the remainder of the season. Chlordan in combination with the fungicides at the dosage levels discussed did not injure the turf.

SUMMARY.—DDT, toxaphene, benzene hexachloride, chlordan and parathion treatments applied to Japanese beetle grub infested turf in 1946 and 1947 were followed carefully in residual activity during the season of 1948. It was seen that DDT after 30 months retained sufficient toxicity in turf to hold grub populations at a non-injurious level. Both toxaphene and benzene hexachloride gave good control at the end of 18 months. This was especially noticeable at the highest dosage levels. Chlordan at both high and low dosage levels was effective at the end of 18 months. Parathion showed no residual activity in less than 12 months. Chlordan displayed sufficient residual activity for ant control in turf to prevent significant re-establishment of the insects at the end of a year. At prescribed dosage levels insecticides discussed did not injure grass. At extremely high levels clover and bent grasses were retarded temporarily.

[2] Puraturf, Puraturf 177, *Crag 531, Pfizer's Mixture, G.&O., Semisan, Calo-Clor* and *Tersan.*

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Some New Insecticides—Their Effect on Plants and Soils

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I welcome this opportunity to participate in your discussion of the effects of some new insecticides on plants and animals. The simple fact that some of the new materials are extremely potent as insecticides suggests in itself the need for testing them for possible adverse effects on plants and animals. That you are aware of such possibilities is evident from the scope of your program this morning.

My remarks will be confined to the phytotoxic effect of some of the new insecticides on plants and soils, based primarily on studies in our Bureau during the past four years at Plant Industry Station, Beltsville, Maryland. A preliminary report on some of this work was made to this group at your meeting last year by Mr. A. C. Foster, of our Division of Fruit and Vegetable Crops and Diseases, who has carried on most of the experimental work. Much of our work has been done in cooperation with entomologists in the Bureau of Entomology and Plant Quarantine. Work of this type has also been carried on by others at various places in a number of States. Most of their findings have not yet been published. In this discussion I will summarize our findings up to now.

Since DDT was first introduced for civilian use in 1945, millions of persons have learned first hand of its superior insecticidal qualities. Almost immediately it received widespread acceptance. In all parts of the country it is being used to kill insects in homes, in farm buildings, on gardens, and on fields.

Other chlorinated hydrocarbons have been introduced since 1945 that are even more effective than DDT in the control of certain insects. These too have been rapidly accepted. Some are being used extensively without sufficient knowledge of their effects on the plants and soils to which they are being applied. Benzene hexahydrochloride and chlordan—like DDT—are relatively stable in the soil.

Chlorinated camphene (toxaphene) does break down under certain conditions. These chemicals present a problem if residues that prove harmful remain in the soil.

In commercial practice different amounts of DDT are now being used on crops in the spray program to control harmful insects. For example, on orchard crops at the rate of one pound to 100 gallons with four or five seasonal applications the total may be 50 to 80 pounds to the acre. With tomatoes and cucurbits on the West Coast the amount may be 30 pounds to the acre for the season. Similarly, with corn in Florida, amounts up to 60 pounds to the acre have been used. While with potatoes the amount may be only 6 to 10 pounds and with peas 2 pounds for the season. These represent amounts applied as foliage applications. With some crops, up to 10 to 15 pounds to the acre have been added directly to the soil for the control of certain soil-infesting pests.

Our experimental work has been divided into two distinct lines of investigations. We are studying the effects of the materials on the growth of the plant, such as germination of seedlings, when mixed with different types of soil at different concentrations and we are studying the toxic effects of these chemicals when applied to the foliage of plants in different formulations and concentrations as used for insect control.

In our experiments with DDT, benzene hexachloride, chlordan, and toxaphene we are using a wide range of concentrations in the soil, from amounts representing the accumulation of a single season's applications up to 10 or 20 times such amounts. These heavy applications are intended to simulate several years' accumulations.

We have found that all four of these chlorinated hydrocarbon insecticides will depress growth of some seedling plants when applied to the soil, even in small amounts (25 pounds per acre). Plant growth is depressed even more with a higher soil concentration. Root development may be retarded with some plants. Root systems are injured more by benzene hexachloride and Chlordan than by DDT. Benzene hexachloride is the only one of the four materials that has been found to affect the flavor of some plants or edible plant parts.

DDT, when applied to the plant foliage or to the soil will retard the growth of certain sensitive plants without any other obvious symptoms. Many crops appear to be highly tolerant to residue of DDT in the soil, but some are sensitive. The potato varieties tested: Cobbler, Sebago, and Katahdin, proved highly tolerant. Golden Cross hybrid corn was also tolerant. The phytotoxicity of benzene hexachloride differs greatly from DDT in that all vegetable crops tested appear to be sensitive to it when it is mixed with the soil in appreciable amounts. Chlordan mixed in the soil is more toxic to seedling plants than benzene hexahydrochloride. Chlordan at the rate of 25 pounds per acre is the only one of the insecticides tested that severely affected the germination of seeds. With benzene hexachloride emergence is affected but not germination. The toxicity of toxaphene appears to decrease with time. This compound is evidently destroyed by soil fungi or bacteria.

Higher concentrations of DDT in soil appear to render seeds of many plants more susceptible to invasion by pre-emergence and post-emergence damping-off organisms. Benzene hexachloride and chlordan have the opposite effect . They often seem to act as fungicides or fungistats in the soil, inhibiting the growth of damping-off organisms.

In other words, we have found many differences in the growth reaction of plants to these compounds. The problem of accumulation in the soil is common to all of them except toxaphene under our experimental conditions. It was recognized early that these materials were relatively stable in soil. That the materials accumulate in the soil has been substantiated by experiments.

In 1945 DDT was added to soil in greenhouse experiments. In the spring of 1946 that soil was removed to coldframes out of doors and has been subjected to weather conditions for the past three years. No additional DDT has been added and seedlings have been grown in these coldframes for three seasons. Injury was still apparent during the past season on those plots that showed injury in 1945. This work and work by others clearly showed that DDT can persist in the soil for a long time.

One of the first observations made in our studies was the response of plants on different soil types when DDT was mixed

with the soil. Plants showed no toxicity when as much as 1000 pounds of DDT per acre was applied to acid muck soil. Injury to plants has been noted on soils low in organic matter when the rate of application was as low as 25 pounds per acre. When the pH of acid muck soil was raised from 4.5 to 5.4 by the addition of dolomitic lime, phytotoxicity was apparent at much lower concentrations of DDT.

It is apparent that the toxicity to plants varies with different soil types. This may help to explain some of the conflicting results reported from experiments carried on in different parts of the country in which plants were injured at one concentration in a given locality but showed no injury from the same concentration in another locality. For example, in a recent report of work carried on in Oregon in 1947 by Morrison et al., benzene hexachloride at the rate of 10 pounds gamma isomer (0.787 pound per 1000 cubic ft.) caused no injury to beans at one location on a soil classified as cove clay while at another location about 40 miles distant on a soil classified as Chehalis fine sandy loam an application at the rate of 27.5 gamma isomer (1010 pounds per 1000 cubic ft.) injured beans. The same method of distribution was used in both cases. The uninjured variety on the sandy soil was Blue Lake while the injured varieties on the clay were two selections of Blue Lake. In this experiment benzene hexachloride was decidedly toxic to a considerable number of vegetables while others were tolerant to a high degree.

We don't know what changes take place in the soil when these chemicals are added that may affect the degree of phytotoxicity to plants. We do know that the DDT chemicals can be dehydrohalogenated. Plant injury may be quite severe when the PP′, OP′ DDT and the dehydrohalogenated analogs are added to the soil. We still need to learn how much of the injury resulting from accumulation is due to decomposition products and how much is due to some by-product or impurity in the chemical. Highly purified DDT preparations were less toxic than some commercial or technical grades.

Not only is there a difference in the response of the same plant on different soil types, but there is also a difference in the toxicity and response of different plants in the same soil. For example, at Beltsville, Maryland, on Sassafras loam, 25 pounds of DDT to the acre injured Abruzzi rye, while Black Valentine beans showed less injury. When lime was added to the soil the Black Valentine beans showed severe injury, but the DDT appeared to be less toxic to the rye.

We have even found differences in the response of the same species of plants under similar soil conditions. Lima beans offer an example. The Triumph variety was severely stunted by the application of 0.075 per cent wettable DDT, but the Peerless variety—a sisterline—showed no injury under the same conditions. Furthermore, 13 other varieties of lima beans on the same experimental plot were not injured when tested with the same formulation.

That the toxicity to sensitive plants increases with greater amounts of DDT in the soil was emphasized with field experiments on Black Valentine beans and Abruzzi rye last summer following applications of DDT in the summer of 1947. With 25 pounds per acre of DDT mixed in the soil, plant growth of Black Valentine beans was reduced about 20 per cent, and bean yield was reduced about 18 per cent. With 50 pounds, plant growth was reduced about 30 per cent and bean yield about 20 per cent. With 100 pounds, plant growth was reduced 41 per cent and bean yield about 33 per cent. With 200 pounds, plant growth was reduced 82 per cent and bean yield about 57 per cent.

Abruzzi rye showed the same type of response. With 25 pounds of DDT per acre the yield was reduced about 12 per cent; with 50 pounds about 18 per cent; with 100 pounds about 19 per cent; and with 200 pounds 33 per cent.

Similar toxic effects were obtained with Rosen rye and Wong barley.

The single minimum application of these new compounds required to control specific insect enemies of one crop or another generally do not produce any recognizable symptom of plant injury. On most crops the accumulated effects of a single season's use produces no visable evidence of injury. There are, however, some important exceptions on certain varieties of squash, of lima beans, and of tomatoes under some conditions. Generally, though, the problem arises from the accumulation of these compounds in the soil when they are used year after year.

Some plants are sensitive to DDT when it is applied to the foliage, but there is a difference in the response of plants depending upon the medium in which the insecticide is applied. Most plants show no injury, for example, when a concentration of dust has been applied directly to the foliage. But when a wetting agent is applied with the material, leaves of some plants become yellow. Tomato plants sometimes show epinasty or bending. Bean plants show chlorosis when DDT is applied to the foliage in the form of an emulsion.

During our 4 years of study it has been noted that the Cucurbitaceae as a family are quite susceptible to varying concentrations of DDT. Varieties of cucumbers and squash show marked chlorosis and the yellow crook neck squash is sometimes injured severely.

These chemicals when applied to plants frequently show results similar to those obtained from more active growth-modifying chemicals such as naphthaleneacetic acid and 2,4-dichlorophenoxyacetic acid. Tomatoes show a curling effect similar to that noted when growth-promoting chemicals are applied to these plants.

Direct plant damage from foliage application, however, appears to be only a minor problem compared with the problems accompanying an accumulation of DDT in the soil. The big question here is whether large amounts of the material will accumulate in the soil from foliage applications. If large amounts should accumulate in this manner, would the toxicity be the same as when an equal amount of the material is mixed directly with soil at one time?

We have a few clues to the answers of these questions but more information is needed. Orchard applications often total as much as 50 pounds of DDT per acre per year. During the 3 years in which DDT has been used on commercial orchards there have been no reports of tree injury. That does not mean the material has not accumulated in the soil. It simply bears out our belief that in addition to being stable these materials also do not move in the soil. If there has been an accumulation it would be on or near the surface.

In other words, we would not expect injury from foliage applications to show up on all deep-rooted plants, such as trees and woody ornamentals. But we cannot overlook the possibilities of soil problems developing similar to those following the use of arsenate of lead on orchard trees, where the orchard is eventually removed and the land used for other purposes.

We have not conducted specific experiments to study the effect of DDT drip from foliage applications on the growth of cover crops. Such an experiment will need to include several different cover crops because some are more tolerant of DDT than others. Oats, for example, is quite tolerant, while rye is quite susceptible.

Goldsworthy has shown that peach roots in sand culture were injured when they were in contact with DDT mixed with the sand at the rate of 25 pounds per acre. When the trees were grown in soil, however, injury was not observed until much greater concentrations of DDT were used. Again, the effect varied with soil type.

Strawberry plants set in Sassafras sandy loam soil in the field at Beltsville, Maryland, in which DDT had been mixed at rates ranging from 12 to 100 pounds per acre, were injured. The roots were stunted in growth and the severity of injury was greatest at the highest concentrations.

Fleming has recently reported that chlordan, which was effective in controlling Japanese beetle when used at the rate of 10 pounds per acre, had no harmful effect on most of the strawberries tested. A few of the vegetables, strawberries, and annual flowers were affected adversely.

Our experiments so far indicate that young growing seedlings are most susceptible to toxicity from DDT accumulations in the soil. Even then, light applications—10 to 15 pounds to the acre per year—may not cause injury to seedling plants. But we need considerably more research before we can be certain of this point. In view of the possible rapid accumulation of these materials in the soil it would seem to be wise practice to use only the minimum dosage necessary for insect control on a particular crop, in order to reduce to a minimum the amount of residue that may accumulate in the soil.

I should like to say a word about parathion. Preliminary observations indicate that this chemical may not persist in the

soil as long as some of the chlorinated hydrocarbons. Our soil studies with this material have not been extensive enough to form any conclusions. We need additional information on the possible breakdown of this material by soil flora.

Research during the past 4 years has brought to light a lot of questions that need to be answered. Even though many answers are still to be found we now have some basic facts with which to proceed—and that is important.

Here is a general summary of what has been found out up to now:

1. Four years after DDT and some other chlorinated hydrocarbons were incorporated in the soil these materials, or others derived from them are still toxic to plants.
2. The toxicity to plants varies with different soil types.
3. Some plants are more susceptible to these chemicals than others, and we find differences even within varieties of plants.
4. These chemicals when applied to plants frequently cause changes similar to those obtained from more active growth-promoting chemicals such as 2,4-D.
5. We need a considerably expanded research program carried on under different soil and climatic conditions with different crops as a basis for more satisfactory soil management and crop protection practices.

On the basis of this information we expect to initiate more intensive soil studies. We want to try to develop methods for decreasing the toxic effects of these materials in the soil.

We should know what materials might be added to soils low in organic matter to adsorb the chemicals. It appears that the explanation for less toxicity in soils high in organic matter may be a matter of adsorption. With the use of certain sensitive plants we hope to establish a biological assay that will be valuable in determining initial toxicity, as well as accumulated toxicity after standing.

We have a number of soils to which DDT was added 3 years ago. These have been undisturbed, and will be examined in the near future to determine changes that have taken place in the PP′ DDT during that period.

A large number of experiments are needed on a wide variety of crops under different soil and climatic conditions. Results obtained with vegetable plants in some of the acid muck soils in the Eastern United States may be quite different from those obtained on alkaline muck soils in other parts of the country. We will need information on the response of the same crop and even the same variety when grown on different soils under various climatic conditions. We need more information on how these materials affect the physiological processes of plants. Are they translocated within the plant? If not, how are objectionable flavors from some of these chemicals imparted to edible plant parts.

We need more research to study this general problem on a large scale, because of its complexity. It is important to develop safe limits, controls, and "antidotes" for use with these new materials. When information from a large number of carefully controlled experiments is obtained, we will have a basis for recommending more satisfactory soil management and crop protection practices.

In any discussion of the effects of these chemicals on plants and soils we must not lose sight of the fact that the use of these valuable chemicals has been responsible for increased yield of fruits, vegetables, and field crops. Cost of production per acre has been reduced in many cases since these chemicals have come into general use in the control of insects hitherto difficult to kill with the best known insecticides.

We most certainly would not recommend throwing these new materials overboard simply because there is so much still to be learned about them. But we do want to emphasize that farmers and gardeners using these chemicals should be informed of their limitations, as well as their benefits, in order that they may recognize the possible hazards inherent in their application.

SCIENTIFIC NOTES

Control of Black Fly Larvae in Alaskan Streams by Aerial Applications of DDT[1]

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During the summer of 1948 a number of experiments were conducted in which DDT-oil sprays were applied to streams in Alaska with airplane equipment to determine the distances downstream such treatments would eliminate black fly (Simuliidae) larvae. The mountainous terrain and the scarcity of roads made it impossible to reach most of the streams in Alaska with ground equipment. Some of the terrain was sufficiently rugged to preclude even the use of airplanes for the control of these insects.

METHODS.—Airplane spray concentrate containing 20 per cent of DDT, 40 per cent of a solvent[2] and 40 per cent of fuel oil was applied to streams with L-5 and C-47 airplanes. Both planes were equipped with wing-bar spray equipment. The L-5 was calibrated to deliver 0.2 pound of DDT per acre (1 pint of 20 per cent solution) with a 100-foot swath, and the C-47, 0.1 pound per acre (½ pint of 20 per cent solution) with an 800-foot swath. The planes flew 50 to 100 feet above the water, and in all but one test the treatments were applied by spraying one or more swaths at right angles across the stream. When more than one swath was applied, each was across the same section of the stream. A 2,400-foot section of one stream was treated by spraying downstream for this distance.

The larval populations were determined before and after spraying by checking rocks, sticks, and the trailing vegetation in streams. Control in all tests was based on the distance downstream in which there was total elimination of larvae. In the tests on the Chatanika River, control was calculated by counts before and after treatment on 4 to 10 rocks at a number of locations below the treated section of the stream. These counts were made by direct observation through the bottom of an Erlenmeyer flask held partly under water in order to avoid disturbing the rocks on which the larvae were attached.

RESULTS.—As shown in table 1, a 0.2-pound dosage of DDT per acre, applied with a 100-foot swath, caused all black fly larvae to detach for 0.5 mile downstream. Four 100-foot swaths at this dosage caused complete detachment for 2 miles. With 0.1-pound dosages applied to 800 to 2,400 foot sections (one to four swaths with the C-47) of streams, complete control was obtained from 1 to 2.5 miles downstream. There appeared to be no correlation between the length of the treated sector and the distance downstream the application was 100 per cent effective. The percentage of partial detachment downstream in the Chatanika River, however, was somewhat greater where longer sections were treated. Counts of larvae on rocks before and after treatment gave the following percentages of detachment below the point of application: For the 800-foot application 92 per cent at 3.5 miles; for the 1600-foot applications, 81 per cent at 4 miles, 70 per cent at 5 miles, and 58 per cent at 7.5 miles; for the 2,400-foot application, 88 per cent at 6 miles, and no reduction at 11 miles. No discernible differences in the resistance of the various species of black fly larvae were noted.

In connection with the routine spraying of one of the Army areas, a station for the study of black fly biology was inadvertently treated on June 13. The population of *Similium venustum* Say and *S. vittatum* Zett. larvae was completely eliminated from the stream and, although eggs and small larvae were observed at intervals after July 10, the larvae did not develop. The first larvae to remain and pupate were noted August 10. It was not known whether residual DDT prevented development of the larvae or DDT continued to drain into the stream from the headwater bogs in sufficient quantity to kill the newly hatched larvae.

[1] This work was conducted under funds allotted by the Department of National Defense to the Bureau of Entomology and Plant Quarantine.

[2] *Velsicol AR. 50.*

Table 1.—Distance that DDT-oil sprays were effective in causing complete detachment of black fly larvae in streams. Alaska, 1948.

STREAMS	SPECIES	POUNDS OF DDT PER ACRE	LENGTH OF APPLICATION IN FEET	MILES OF 100 PER CENT DETACHMENT
Chester Creek	*Prosimulium onychodactylum* D. & S.	0.2	100	0.5
Wasilla Creek	*Simulium arcticum* Mall.	.2	400	2
		.1	800	2.5
		.1	800	2
Paul River	*S. vittatum* Zett.	.1	800	2.5
Fish Creek	*S. venustum* Say—*vandalicum* D. & S. complex	.1	800	2
Chatanika River	*S. arcticum* Mall, *S. corbis* Twinn, and *S. venustum-vandalicum* complex	.1	800	1.5
		.1	1,600	2
		.1	2,400	1
Naknek River	*S. arcticum* Mall., *S. vittatum* Zett.	.1	1,600	1.5

Effect on the Dark Rice Field Mosquito[1] of Feeding on Cows Treated with DDT[2]

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There is a widespread assumption that DDT sprayed on livestock will protect them from mosquitoes. At any rate, most distributors of DDT and numerous entomologists recommend it for this purpose.

Much evidence has been presented indicating that mosquitoes, both larvae and adults, are quite susceptible to DDT. This material used as a residual spray on walls of buildings or as a space spray in the form of aerosols has been proven very effective against the adults. It is also well known that the spraying of cattle with DDT has been very effective in the control of the horn fly which also is quite susceptible to DDT. Bruce & Blakeslee (1946) noted sharp declines in mosquito populations following programs where all livestock and outbuildings in certain areas had been sprayed with DDT.

Such facts probably are responsible for the above mentioned assumption.

The writer has recently taken over the problem of mosquitoes in the rice growing areas of Arkansas. Horsfall (1942) has discussed the scope of this problem and completed much work on the biology of the species involved. In a consideration of the various angles of approach to the control of these species, the spraying of all livestock in a given area was considered worth investigating.

An experiment was therefore conducted during the season of 1948 in which all livestock and outbuildings within a mile radius of an isolated rice field were sprayed with DDT at approximately 2-week intervals from the middle of May to the latter part of June. While data taken gave some indication of a reduction in population, the mosquito problem remained severe. Such results aroused doubt in the mind of the writer concerning the efficacy of livestock spraying for mosquito control and the following experiment was devised to obtain further information on the subject. This experiment was conducted as the opportunity presented itself in connection with other work, and is presented as a preliminary report.

TECHNIQUE.—Cylindrical cages, 3 inches in length, were constructed of 16 mesh screen wire of a diameter that would just fit inside of a number 63, two-piece jar lid, 2.25 inches in diameter. The center pieces were removed from the lids and replaced with circular pieces of screen soldered to the inside of the lids. One of the lids was soldered to the cage, the other left free to slip on and off. Other jar lids of the same size, with the center pieces removed, were glued to canvas in such a position that when the canvas was placed in position on a cow, the lids would be high on the cow's back. The canvas was then cut from the open center of the lid. With this arrangement whenever a cage containing a mosquito was fitted into the jar lid glued to the canvas, the caged mosquito had free access to the cow, and it was found that under these circumstances a high percentage of the mosquitoes thus confined would drop to the cow's back and feed to repletion. When feeding was completed, most of them would come up and rest on the side or top of the cage. By observing the mosquitoes in this position, one could readily determine whether or not they had fed.

Three cows were selected from the dairy herd of the Rice Branch Experiment Station. Two of them were treated with a suspension of DDT in the form of a 50 per cent wettable powder in water, and the remaining cow was left untreated. For one cow, the powder was used at the rate of 20 pounds per 100 gallons of water; for the other, 5 pounds per 100 gallons. The suspensions were applied by mopping the backs of the cows with a cloth soaked in the suspensions until their backs were thoroughly wetted.

Mosquitoes were obtained by going to a convenient place where they were numerous and placing a cage over the mosquitoes lighting on the clothing. When they flew up into the cage, a lid was slipped under them and onto the cage. The cages were then placed in an open box kept in the shade. When a sufficient number had been caputred, the cages were taken into the barn where the experimental cows had been placed in stanchions. The canvas, to which the jar lids had been glued, was placed in position on each cow, care being taken to see that the same canvas was used on the same cow each time. The lid of each cage was then removed, and the cages quickly fitted into the jar lid glued to the canvas. The cages were examined every few minutes and as soon as replete females were found, the cage with the mosquito in it was removed and replaced with a cage containing a female that had not as yet had the opportunity of feeding. Any that had not fed in from 30 to 45 minutes after being caged on the cow were discarded. Records were kept of the number that were placed on each cow as well as the number feeding.

When the feedings were completed, the cages were taken to a basement room and covered with damp towels, those from each cow being kept separate. The feedings were conducted during the afternoon hours and records taken as to the number dead or alive the following morning, approximately 16 hours later. Any mosquitoes that were down and could not be induced to assume an upright position were counted as dead even though they might still be able to move their appendages.

All of the experiments reported herein were conducted with *Psorophora confinnis* (L.-A.)

Results and discussion. Table 1 summarizes the results of these experiments.

The data presented indicate that DDT used on cattle at the rate of 20 pounds of 50 per cent wettable powder to 100 gallons of water kills approximately 84 per cent of the mosquitoes feeding during the first few days after treatment. Approximately 50 per cent are killed during the balance of a 9-day period, but very few thereafter.

DDT used on cattle at the rate of 5 pounds of 50 per cent wettable powder to 100 gallons of water kills approximately 75 per cent of the mosquitoes that feed on such cattle for a period of 3 days, but has little effect thereafter.

In comparison with the results obtained against horn flies and with residual sprays on walls, such kills are disappointingly small and of short duration. It is believed that the less favorable results thus obtained are accounted for by the brief period of time that the mosquitoes spend on cows, and consequently, in contact with the DDT. No attempt was made to determine the exact amount of time the

[1] *Psorophora confinnis* (L.-A.).

[2] Research paper No. 871 Journal Series, University of Arkansas, published with the permission of the Director of Arkansas Agricultural Experiment Station.

Table 1.—Effect on mosquitoes of feeding on cows treated with DDT.

Days Between Treatment of Cow and Feeding of Mosquitoes	Cow #1 20 lbs. 50% DDT per 100 gallons		Cow #2 5 lbs. 50% DDT per 100 gallons		Cow #3 No treatment	
	No. feeding[1]	Per cent dead after 16 hrs.	No. feeding[1]	Per cent dead after 16 hrs.	No. feeding[1]	Per cent dead after 16 hrs.
1– 3	81	84	67	75	71	11
4– 6	76	54	60	18	33	6
7– 9	40	53	27	25	32	6
9–14	38	5	40	15	31	6
Total	235		194		167	

[1] The total number of moquitoes applied to cow Number 1 was 429; Number 2, 381; and Number 3, 350. Total number applied to all cows, 1160.

mosquitoes spent in contact with the cows, but observations made during the course of these experiments indicate that such periods were quite brief. Frequently, replete females were found in the first cages applied by the time the last were placed in position, a period of less than 5 minutes. Also whenever they were seen feeding, they were generally up on the side of the cage a short time later. At any rate, the time spent on the cows is certainly far less than that of horn flies that spend practically their entire adult life on cattle and probably far less than the time typically spent on a sprayed wall by mosquitoes alighting there to rest or to digest a meal.

Of the 439 mosquitoes offered the opportunity of feeding on the cow treated with the heavy dosage, 235 or 55 per cent fed. Of the 381 placed on the cow with the lighter concentration, 194 or 51 per cent fed, while of the 350 placed on the untreated cow, 157 or but 48 per cent fed.

Since no tests were run previous to the treatment of the cows, it is entirely possible that there may have been variations in the attractiveness of the individual cows to mosquitoes. However, the data obtained indicate that DDT has no repellent effect at all and therefore will give no protection to cattle from adult mosquitoes already present.

Summary and Conclusions.—Individual mosquitoes were caged on cows treated with two concentrations of DDT. Mortality records were taken on those that fed. These records indicated that DDT applied to cows at the concentrations used, even when recently applied, does not result in complete control, and that its effectivness is of short duration. They also show that DDT does not protect cattle from mosquitoes by acting as a repellent. It appears that if cattle are to be sprayed with DDT in an attempt to control mosquitoes, it must be used at high concentrations and applied frequently. Since there is a possibility that such treatments may constitute a hazard to the consumers of the products of animals thus treated, and since the control is only semi-satisfactory, it seems questionable whether DDT should be recommended for the control of mosquitoes on cattle.

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Insecticidal Tests of Some New Organic Phosphates[1]

H. J. Ball and T. C. Allen[2]

Following World War II, examination of German patents revealed a new insecticide possessing toxic qualities greater than those of DDT for certain insects. This insecticide introduced from Germany was known as hexaethyl tetraphosphate, the preparation and description of which has been recorded by Schrader (1943, 1947). Several investigators (Bronson & Hall, 1946, Chapman & Allen, 1947, Fayette *et al.*, 1946) found it to be of special use in controlling such pests as aphids and mites. Previously, DDT had failed to give good control of some of these pests.

Later chemical investigation in this country revealed another highly toxic phosphate compound, tetraethyl pyrophosphate which was about three to four times as toxic as hexaethyl tetraphosphate to certain insects and mites. Subsequent research showed that the toxic material in hexaethyl tetraphosphate was tetraphyl pyrophosphate (Hansen 1947). However, both these insecticides possessed characteristics which tended to limit their use. The most important of these was the fact that they had very little residual toxicity due to their tendency to hydrolyze. Difficulty was also encountered in making proprietory dust mixtures with such products as they tend to lose their toxicity in storage.

The answer to the need of a phosphate insecticide which would be stable in the presence of moisture and still possess the remarkable killing power of the pyrophosphates was parathion. This closely related chemical, o, o-diethyl o-p nitrophenyl thiophosphate, is known for its rapidity in killing action as well as its prolonged toxicity to a large number of insect species (Creighton & Graham 1947; Leiby 1948; Jones & Rosentiel 1948).

More recently newer compounds of the phosphate type having still greater toxicity to insects than parathion have been found according to laboratory screening tests at Wisconsin. The new compound named diethyl paranitro phenylphosphate[3] which has been described earlier in Germany (Schrader 1947), is an analog of parathion and causes for its

[1] Supported by a fellowship grant from Victor Chemical Works.

[2] Approved by the Wisconsin Agricultural Experiment Station.

[3] Supplied by Victor Chemical Works.

increased toxicity above that of parathion may be due to the substitution of an oxygen for a sulfur group in the phosphate moledule. The compound is a light yellow liquid with practically no odor, having a specific gravity of 1.269. It is soluble in most organic solvents, but is fairly insoluble in spray oils unless a mutual solvent is added. At normal temperatures it is stable to hydrolysis.

In the following laboratory tests, the insecticidal potentiality of diethyl paranitro phenylphosphate was compared with three other highly effective phosphate compounds. These were: parathion; tetraethyl pyrophosphate technical, a modified hexaethyl tetraphosphate product; and tetraethyl dithiono pyrophosphate,[2] a compound related to tetraethyl pyrophosphate. Comparative laboratory tests were made with these materials against the housefly, *Musca domestica* (L.), milkweed bug, *Oncopeltus fasciatus* (Dall.), potato aphid, *Macrosiphum solanifolii* (Ashm.), pea aphid, *Macrosiphum pisi* (Kltb.), and the German roach, *Blatella germanica* (L.).

Table 1.—Relative percentage kill of houseflies.

Material	Per Cent Kill in Oil Base	
	1–8000	1–16,000
Diethyl paranitro phenylphosphate	86.0	65.0
Parathion	43.0	10.0
Tetraethyl dithiono pyrophosphate	3.3	3.3
Tetraethyl pyrophosphate technical	1.7	0.0

Table 2.—Relative percentage kill of milkweed bugs.

Material	Per Cent Kill in Water at Following Dilutions				
	1–250	1–500	1–1000	1–2000	1–4000
Diethyl paranitro phenylphosphate	100	100	95	70	70
Parathion	90	35	35	5	0
Tetraethyl dithiono pyrophosphate	85	20	20	5	0
Tetraethyl pyrophosphate technical	65	35	25	5	0

Tests on the potato aphid were made after rearing the aphids on potato and then spraying them on small squash plants after they were established thereon.

Table 3.—Relative percentage kill of potato aphid.

Material	Per Cent Kill in Water at Following Dilutions		
	1–8000	1–16,000	1–32,000
Diethyl paranitro phenylphosphate	100	97	88
Parathion	94	66	50
Tetraethyl dithiono pyrophosphate	88	46	29
Tetraethyl pyrophosphate technical	43	13	12

The pea aphid was removed from plants in the field and brought into the laboratory for testing with dusts made from the materials listed in Table 4 below.

Table 4.—Relative percentage kill of the pea aphid.

Material	Per Cent Kill with Dust at Following Dilutions				
	.01	.005	.0025	.00125	.00063
Diethyl paranitro phenylphosphate	x[1]	x[1]	100	77	15
Parathion	91	73	47	x[1]	x[1]

[1] Not tested.

The potato aphid was also tested with dusts. Table 5 shows the results of these tests.

Table 5.—Relative percentage kill of the potato aphid

Material	Per Cent Kill with Dust at Following Dilutions				
	.01	.005	.0025	.00125	.00063
Diethyl paranitro phenylphosphate	x[1]	x[1]	97	52	20
Parathion	97	92	57	x[1]	x[1]

[1] Not tested.

The German roach was tested as follows with dusts in the same manner as the pea and potato aphid.

Table 6.—Relative percentage kill of the German roach.

Material	Per Cent Kill with Dust at Following Dilutions				
	.01	.005	.0025	.00125	.00063
Diethyl paranitro phenylphosphate	x[1]	x[1]	100	100	100
Parathion	100	100	60	x[1]	x[1]

[1] Not tested.

Residual activity was tested by spraying the four materials in water solution on petri dishes at a concentration of 1–500. The plates were dried and then were tested at four, eight, and twelve days against milkweed bugs.

Table 7.—Relative percentage kill of the milkweed bug.

Material	No. of Days Following Spraying		
	4	8	12
Diethyl paranitro phenylphosphate	100	65	0
Parathion	40	45	0
Tetraethyl dithiono pyrophosphate	10	0	0
Tetraethyl pyrophosphate technical	0	0	0

These trials showed that diethyl paranitro phenylphosphate has promising qualities as an insecticide. At a concentration of 1 to 1000 it is almost three times as toxic as parathion to milkweed bugs. In an aqueous spray on potato aphids at a concentration of 1 to 32,000 it shows an increase in kill of over 50 per cent as compared to parathion. In dust form on both the pea and potato aphid it appears

to be about twice as toxic as parathion. The same is true for the German roach. In a base oil as used in fly sprays it appears to be twice as toxic as parathion at a concentration of 1 to 8000.

Tetraethyl dithiono pyrophosphate appears to possess greater insecticidal effectiveness than tetraethyl pyrophosphate technical grade against both houseflies and milkweed bugs, but does not compare favorably in toxicity with diethyl para-nitro phenylphosphate or parathion.

Results of phytotoxicity tests to several truck crops grown under field conditions showed these new materials to be quite safe for use at insecticidal levels. In general little is known of the relative poisonous hazards of these newer compounds to plants and animals or their products, but their high toxicity to insects at low concenttrations would certainly warrant further consideration of them for insecticidal uses.

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[2] Identified commercially as ASP-47.

An Application of Double Sampling in Evaluating Insect Infestations

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In many biological and agricultural investigations the labor of determining results is a limiting factor. Examinations of citrus fruits for infestation of scale insects or of ears of corn for earworm infestation are examples. In some such cases "double sampling"[2] may be applied.

A large number of fruits sampled randomly from each plot may be separated rapidly into several categories, such as uninfested, and lightly, moderately, and heavily infested. A random subsample of a few fruits may then be taken from each class, and the insects on each fruit may be carefully counted. Multiplying the proportions of each class by its average number of insects will give an unbiased estimate of scale population with a limited amount of labor. Such a procedure used on a large number of fruits may result in a more accurate evaluation than a complete count on a smaller number.

The labor of examination is important in corn earworm research, as large numbers of strains of corn from replicated experiments must be examined by a limited force of workers. The percentage of ears attacked has not proved very precise; the extent of attack on each ear is a much more critical measure. At first, efforts were made to approximate the number of grains destroyed on each ear. This method proved very informative, but not practicable on account of the labor involved. Hence a system was worked out by which ears of field corn could be separated rapidly into the following classes:[3]

Class	*Grains destroyed*
1	0 to 5
2	6 to 15
3	16 to 25
4	26 to 40
5	Over 40

These classes were used in evaluating strains of corn as to susceptibility to earworm attack. The ordinal class numbers have sometimes been used in adding, averaging, and other analytical operations, by plant and insect scientists. However the procedure is not desirable, since it implies that class 2 is attacked twice as heavily as class 1, class 3 three times as heavily, and so forth, These implications are obviously not accurate. It has also been found that use of these class numbers in analysis may not give the full value of comparisons.

R. A. Blanchard and the writer assigned the following weights to the classes, as estimates of average numbers of grains destroyed:

Class	*Grains destroyed*
1	3
2	10
3	20
4	33
5	60

[1] Now with Production and Marketing Administration, U. S. Department of Agriculture.

[2] Cochran, W. G. 1939. The use of the analysis of variance in enumeration by sampling. Amer. Statis. Assoc. Jour. 34: 492–510.

[3] Credit for this work should be given F. F. Dicke, R. A. Blanchard, and E. V. Walter, of the U. S. Bureau of Entomology and Plant Quarantine, and R. H. Painter, of Kansas Agricultural Experiment Station.

Table 1.—Injury computed with ordinal numbers as weights

CLASS	NUMBER OF EARS	CLASS WEIGHT TIMES NUMBER
0	0	0
1	2	2
2	8	16
3	9	27
4	2	8
5	0	0
Total	21	53

These weights were reduced by division to 1, 3, 7, 11, and 20.

An example of the use of these weights may be taken from one of Blanchard's plots yielding 21 ears. First the ordinal numbers were used (Table 1).

The average is 53/21 or 2.52.

The weights based on actual injury are then used (Table 2).

Table 2.—Injury computed with weights based on destruction.

CLASS	WEIGHT	NUMBER OF EARS	NUMBER OF EARS TIMES WEIGHT
0	0	0	0
1	1	2	2
2	3	8	24
3	7	9	63
4	11	2	22
5	20	0	0
Total	—	21	111

The average is 111/21 or 5.29, and grains destroyed per ear would be estimated as about 3 times this figure.

For each plot an average value can be computed by this method, and the averages used in analysis. The procedure suggested gave satisfactory results with Blanchard's material, and the weights based on destruction gave somewhat more precise comparisons than did class numbers.

A more searching investigation was made in cooperation with T. R. Chamberlin and W. A. Douglas of the U. S. Bureau of Entomology and Plant Quarantine. Chamberlin separated several hundred ears into classes, keeping in mind the limits above and also depth of earworm penetration. Ears showing attack but no grains destroyed were placed in class 1. Grains destroyed were then counted, in each class. There were 50 ears for examination in classes 1, 2, and 3, and nearly 50 in classes 4 and 5. The average numbers of grains destroyed were 0.4, 4.4, 13.6, 37.9, and 59.9 in the respective classes. With 1 as the smallest weight, these averages can be used as weights of 1, 11, 34, 95, and 150. An additional class showed no attack at all.

Analysis was made of a typical set of data from an experiment testing 25 strains of corn with 6 replications in each test. There were from 30 to 60 ears on most plots. For each plot a weighted figure was obtained by multiplying the number of ears in each class by Chamberlin's weight for that class, as in table 2. The percentage of ears attacked was computed for each plot. The class-number totals were also obtained. Each of the three criteria was used in analysis of variance (Table 3).

Table 3.—Analysis of variance of earworm attack calculated using several criteria.

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE FOR—		
		Percentage of ears attacked	Class numbers	Weighted estimates
Replication	5	58.2	0.13	40.7
Strain	24	109.1	0.49	292.7
Error (R×S)	120	25.5	0.05	15.2
F for strains		4.3	9.4	19.2

The weighted estimate is considerably more precise than the class number. The strains ranked similarly by the two methods, but closer discrimination was possible by the use of the weights. This might be expected, since the worst class is given a weight 150 times class 1 by the weighting system, as compared with 5 times by the class-number system. Thus the nonresistant strains are more sharply set apart from the resistant ones. The gain in precision is a legitimate one, as it results from use of estimates of actual destruction. Weighted estimates could readily be converted to crop-loss estimates. In the particular case cited, the gain is equivalent to that obtainable by doubling the replication.

Percentage of ears escaping attack appears very weak in analysis, for two reasons: First, the percentages do not use any of the information as to the extent of attack. A measure for each individual will always give more information for a given number of individuals than the percentage of individuals above and below a limit. Second, complete escape from attack appears not to be a strong varietal characteristic in most varieties of corn used thus far, whereas resistance is definitely characteristic of some strains. Percentage of ears not attacked, or lightly attacked, might be contrasted with percentage severely attacked, with better results, but this procedure could not be expected to be so precise as use of weighted estimates.

If double sampling were fully carried out, subsamples would be counted in each plot. This procedure is not practicable in corn earworm research, since ears per plot are too few and counting is too laborious. On the other hand, determining standard weights once for use in every situation would involve some risk of inaccuracy, since types of corn vary widely in tip condition. Thus the rapidly determined classes may vary from experiment to experiment. Some subsampling and counting should be done in each extensive experiment in order to determine good weights for that particular experiment, and also to keep standardized the process of separation into classes.

Obviously if weights are not perfectly determined, they will be subject to some error, which will add to experimental error. However, such error will affect both strain and error variances, and will not invalidate tests of significance. W. G. Cochran of North Carolina State College has concurred in this view.

Some workers are not primarily concerned with earworm attack, but record it incidentally. The Southern Corn Improvement Conference has suggested standards for bulk examination of all ears from a plot, and classification of the plot as a whole without handling individual ears. Closer examination of a few plots of each class, with rather exact damage evaluation, should give a workable basis for comparisons. Weights derived from such close examinations can be applied to all plot ratings.

It is believed that this weighting method will make possible better use of hard-won experimental data. It should find some application in cases where rapid separation into classes is practiced, and where exact measures can be applied to subsamples.

Further Studies on Control of Red-banded Leaf Roller with Parathion[1]

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A previous report (King *et al.* 1948) gives the results of an experiment conducted in 1947 to determine the relative effectiveness of parathion, lead arsenate and DDT against the red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.). Parathion gave excellent control, but not significantly better than lead arsenate, and DDT gave inferior control.

The work described in this paper is a continuation of the above experiment and was carried out in the same orchard in 1948.[2] The same layout was used. It consisted of 3 separate blocks of trees, 1 each of Cortland, Snow, and Jonathan. The Cortland and Snow blocks were the same blocks that had been used in 1947, but the Jonathan block was new. In each of the 3 varieties a randomized block layout, using single tree plots, was set up. In the Cortland variety there were nine replicates, in the Snow variety seven, and in the Jonathan variety seven, making a total of 23 replicates for each of the treatments.

Standard, uniform, applications of wettable sulfur and lead arsenate were made by the owner of the orchard during the pre-bloom and calyx periods. Beginning with the first cover spray on June 2, the following experimental treatments were applied:

40 oz. of 25% parathion wettable powder
16 oz. of 25% parathion wettable powder
48 oz. of lead arsenate, 16 oz. of zinc sulfate and 64 oz. of lime
32 oz. of 50% DDT wettable powder
check (no insecticide).

The second cover spray was started on June 14, the third cover on June 24, the fourth cover on July 6 and the fifth cover on July 29. In the first three cover sprays, 6 lbs. of wettable sulfur were added to each application, including the check. No fungicide was used in the last two applications. Maximum temperatures on the dates of application ranged from 60° to 90° F. Relative humidity at 1:30 P.M. on the dates of application ranged from 36 to 90 per cent. All treatments were applied with standard orchard sprayers (300 gallon tank, 35 gallon pump, single gun) and all spraying was done from the ground.

At harvest time the yield of each tree was recorded and 100 apples, chosen at random from the crates under the tree, were scored for insect injury and spray injury. The data concerning yield and leaf roller control are tabulated below (Table 1). Analyses of variance indicated no significant differences in yield, but did show highly significant differences in the leaf roller control. At odds of 99 to 1, the significant difference between the percentages of leaf roller injury was 1.5 per cent.

Four sets of apple samples for residue analysis were taken from the Cortland trees during the season. The first was taken 4 hours after the last cover spray was applied and the second, third and fourth at 15, 25, and 66 days respectively, after the date of the last cover spray. Analyses were made by members of the Section of Agricultural Chemistry of the Michigan Agricultural Experiment Station. Their results are tabulated in table 2.

Following the third application, spray injury was observed on the trees sprayed with 40 oz. of parathion. The injury was characterized by wilted, curled and dead terminals. It was definitely related to the application of a high dosage of parathion, but was probably aggravated by unfavorable drying conditions following the third cover spray. Both temperature and humidity increased during the time the spray was being applied and for a period of four days the humidity remained between 85 and 90 per cent. The injury was observed to be relatively severe on Cortlands, moderate on Snows and slight on Jonathans.

Table 1.—Injury by red-banded leaf roller and yield of apples following treatments with parathion, lead arsenate and DDT. Each figure represents the average of 23 single-tree plots.

Treatment	Per Cent Leaf Roller Injury	Yield in Bushels per Tree
40 oz. of 25% parathion	0.7	9.5
16 oz. of 25% parathion	1.7	9.4
48 oz. of lead arsenate	2.0	10.8
32 oz. of 50% DDT	4.3	9.4
Check	9.4	9.4

Table 2.—Parathion residues on apple fruits following spray treatments.

Treatment	40 oz. 25 Per Cent Parathion	16 oz. 25 Per Cent Parathion
	Residual parathion (ppm)	
4 hrs. after last cover spray	6.6	2.4
15 days after last spray	1.0	0.5
25 days after last spray	0.5	0.3
66 days after last spray	0.0	0.0

After the fifth cover spray some injury was noticed on the apples. This injury was in the form of small dark-colored spots scattered over the undersides of the fruit. It was much more in evidence on fruit sprayed with 40 oz. of parathion than on fruit sprayed with 16 oz. of parathion. Many Cortland apples were spotted, but relatively few Snow apples were injured. No spotting was observed on the Jonathans.

At harvest time, two months later, the terminal injury was obscured by new growth, but the fruit injury was even more extensive than it had appeared earlier, especially on the Snows. In the Cortland block 14 per cent of the fruit sprayed with the heavy dosage of parathion showed injury and 3 per cent of the fruit sprayed with the lighter dosage was injured. In the Snow block 16 per cent of the fruit sprayed with the heavy dosage was injured, but less than 1 per cent of the fruit sprayed with the lighter dosage showed injury. In the Jonathan block, there were no spotted fruits; but there was evidence of a different type of injury. Many of the Jonathan apples had

[1] Published by permission of the Director of the Michigan Agricultural Experiment Station. Journal Article number 1006 (n.s.).

[2] This work was supported in part by a grant from the American Cyanamid Company. In addition, the parathion used (Thiophos 3422) was supplied by the company.

been severely russeted in the spring, before the experimental sprays were started. At harvest time the russeting had disappeared on all plots except those sprayed with the heavy dosage of parathion. On those plots the russeting was as severe as it had been in the spring, more than half the apples being of poor quality.

SUMMARY.—In replicated treatments, 5 cover sprays of parathion wettable powder, used at the rate of 10 oz. of actual parathion per 100 gallons of water, gave excellent control of red-banded leaf roller on Cortland, Snow and Jonathan apples, but not significantly better than 4 ounces of parathion or 48 ounces of lead arsenate. 16 ounces of DDT gave inferior control. Spray applications caused no significant change in yield. Chemical analyses indicated negligible residues of parathion 4 weeks after spraying. Spray injury was observed following the heavy dosage of parathion, and to a lesser extent following the lighter dosage.

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Meligethes aeneus as a Factor in Muskmelon Breeding Program in Pennsylvania[1]

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In the summer of 1948, several hundred muskmelon plants, representing about 30 inbred-strains, were grown at the Erie County Field Research Laboratory, North East, Pennsylvania. These plants grown for the purpose of selection, were planted in two fields.

Mature flowers from these muskmelon plants were selfed, the work beginning on July 1, 1948 and ending on July 31, 1948. Field records were taken in regard to the date, air temperature and the time of day at which each flower was selfed. During the period from July 1 to 20, 1948, a total of 253 flowers were selfed. Self pollinations made in the morning showed a percentage fruit set of 21.43 in the north field and 25.93 in the south field. On the other hand, pollinations made in the afternoon showed a percentage fruit set of only 9.38 in the north field and 5.63 in the south field. (Table I, A).

Variations in climatic conditions were thought to be responsible for these great differences; however, careful observations made in the fields revealed that insects[2] were causing destruction of the stamens. These very tiny, dark-colored beetles, emerging around 10:00 A.M. fed on the available muskmelon pollen grains in the mature flowers and by noon had practically cleaned out the anthers.

Table 1.—Percentage fruit set resulting from pollinations made in the morning as compared to those made in the afternoon.

DATE	SELFED IN THE MORNING, PERCENTAGE SUCCESS	SELFED IN THE AFTERNOON, PERCENTAGE SUCCESS
A. July 1–20, 1948		
North field	21.43	9.38
South field	25.93	5.63
B. July 21–31, 1948		
North field	48.78	
South field	54.14	

On July 20, 1948, 50 freshly opened mature muskmelon flowers were collected from the fields at 8:00 A.M. and another 50 from the same fields at 1:00 P.M. of the same day. They were dissected and examined under a binocular microscope. Of the 50 flowers collected in the morning, 90 per cent contained abundant and 10 per cent had a moderate amount of pollen. Of the 50 flowers collected in the afternoon, 76 per cent were without pollen while 24 per cent still had a small available supply. This comparative study indicated why the selfing of muskmelon flowers in the afternoon was likely to fail, at least at the Erie County Research plots this past summer.

The selfing program was carried on only in the early morning for the remainder of the season. The program was stopped daily as soon as the beetles appeared in the fields. During the period from July 21 to 31, 239 flowers were selfed in the morning. The results are shown in table 1, B. The percentage of fruit set in the north field increased from 21.43 per cent to 48.78 per cent (an increase of 127.63 per cent) and in the south field, from 25.93 per cent to 54.14 per cent (an increase of 108.79 per cent). The average increase for both fields was 118.21 per cent. These increases in fruit set resulting from pollinations made in the morning were, of course, obtained by preceding the beetles in the field. In the future, however, a method should be developed for eliminating these beetles so that the selfing work can be carried on throughout the entire day. 12-23-48

[1] Authorized for publication on December 17, 1948 as paper No. 1499 in the journal series of the Pennsylvania Agricultural Experiment Station.

[2] This insect was identified by Mr. Henry Dietrick, Department of Entomology, Cornell University, as *Meligethes aeneus* (Fab.). According to Dr. Stuart W. Frost, professor of economic entomology, Entomology Department, Pennsylvania State College, this insect is native to Europe, and was introduced to the United States. It has been reported in California, Oregon, Indiana, and New York. This is the first known instance of the presence of this insect in Pennsylvania. No common name is yet available.

The Relation to Toxicity of Boiling Point of Low Vapour Pressure Fumigants

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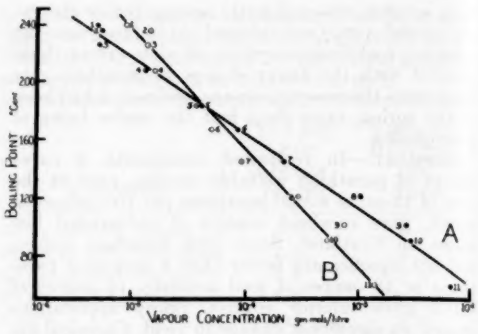
It has long been evident that the relation between the boiling point of fumigants and their toxicity to insects, as found by Moore (1917) and by Tattersfield & Roberts (1920), is primarily a relation between the boiling point of the compound and its consequent vapour pressure. This view has very recently been expressed in quantitative form by Ferguson & Pirie (1948), with supporting evidence. They have drawn a clear distinction between two types of fumigants: physical poisons, which are narcotics and are not broken down in the insect, and which fall on the straight line of the relationship; and chemical poisons which enter into the biochemistry of the body, and are too active to follow this relationship. The latter compounds, which constitute most of the commercial fumigants, had prompted Shepard *et al.* (1937) to conclude that the relation-

ship between toxicity and boiling point did not hold in their studies.

The present communication is offered as supporting evidence for the thesis of Ferguson & Pirie, and raises a new point in connection with fumigants of low vapour pressure. These compounds, since their vapour pressures were less than 0.3 mm. of mercury showed median lethal concentrations of less than 4 mg./litre if purely physical poisons, or less than 1 mg./litre if they were chemical poisons. Results of toxicity tests on *Tribolium*, *Sitophilus* and *Oryzaephilus* with a series of such compounds, employing an exposure period of 5 hours at 25° C. in 20-litre closed glass containers, have been set down in a paper prepared by Brown & Hopewell for publication.

The amount of vapour required to saturate a given volume of air is a direct function of the vapour pressure of the compound, which in turn is colligative with its boiling point.[1] Thus a straight line will be obtained when the boiling points of fumigants are plotted against the logarithm of their molar saturation values. The relationship so derived from the figures listed in table 1 is displayed as Line A of figure 1. The slope of the line is such that the saturation value (C_s) decreases 50-fold for each 10° C. rise in boiling point of the compounds concerned.

If the amount of vapour required to kill 50 per cent of *Tribolium* adults is expressed as the median lethal molar concentration (Table 1) and plotted against the boiling point, a linear relationship is again obtained (Line B of Figure 1). But the slope of the line is steeper, indicating that the toxic concentration (C_t) decreases 90-fold for every 10° C. rise in boiling point. The results of Shepard *et al.* with *Tribolium* adults, when similarly plotted (considering the physical poisons only), indicated an 82-



Line A. Molar concentration at which air is saturated with vapour.
Line B. Molar concentration at which 50% of *Tribolium* adults are killed.
Compounds indicated by numbers, for whose designation see table 1. Toxicity values for tetrachloroethylene (8) and carbon tetrachloride (11) taken from Shepard *et al.* (1937).

FIG. 1.—Relation of boiling point to saturation value and to fumigant toxicity.

[1] The Saturation Value at 25°C.: in mg/litre = Mol. Wt. × Vap. Press. × 1/18.6: or in gm-mols/litre × 10^{-6} ("Molar × 10^{-6}") = Vapour Pressure × 1000/18.6.

Table 1.—Thermodynamic activity of vapours and their toxicity to adults of *Tribolium confusum*: fumigants which may be classed as physical poisons.

No.	Name of Compound	Boiling Point °C.	Vapour Pressure mm. Hg 25°	Median Lethal Concentration		Saturation Concentration Molar × 10^{-6}	Relative Saturation C_t/C_s
				mg./l.	Molar × 10^{-6}		
1	s-Heptachloropropane	240	.092	2.5	8.8	4.9	1.8
2	as-Heptachloropropane	237	.098	4.1	14.4	5.3	2.7
3	Phenylacetonitrile	227	.095	1.6	13.6	5.1	2.7
4	o-Chlorobenzyl chloride	207	0.26	2.3	14.4	13.8	1.0
	p-Chlorobenzyl chloride	207	0.21	2.8	17.5	11.4	1.5
	Benzotrichloride	207	0.25	3.0	15.5	13.4	1.2
	Hexachlorobutadiene	203	0.30	4.0	15.3	16.1	0.95
5	Benzonitrile	188	0.98	5.0	48	53	0.91
6	N-Butyl-morpholine	168	1.5	6.9	48	80	0.60
7	1,4-Dichlorobutane	147	3.7	11	86	200	0.43
9	Benzotrifluoride	100	46	104	710	2500	0.35
10	1,2-Dichloropropane	91	52	57	505	2800	0.18

Table 2.—Thermodynamic activity of vapours and their toxicity to adults of *Tribolium confusum*: fumigants which may be classed as chemical poisons.

Name of Compound	Boiling Point °C.	Vapour Pressure mm. Hg 25°	Median Lethal Concentration		Saturation Concentration Molar × 10^{-6}	Relative Saturation C_t/C_s
			mg./l.	Molar × 10^{-6}		
Dichloroethyl sulphide	215	0.15	0.6	5.0	8.4	0.60
Hexachloropropene	203	0.50	1.1	4.5	27	0.17
Dichloroethyl ether	175	3.0	1.8	12.6	160	0.078
Morpholine	119	17	1.9	21.9	920	0.024
2,3-Dichloropropene-1	93	60	2.9	26.0	3200	0.008
1,1,1-Trichloroethane	74	148	63	495	8300	0.059

fold decrease, Moore's results with *Musca* adults a 78-fold decrease, and Tattersfield & Roberts with *Agriotes* larvae a 70-fold decrease for every 10° C. rise in boiling point.

Thus the relation C_t/C_s, the relative saturation at which the vapour is toxic, is not a constant figure for physical poisons, but tends to increase as the boiling point rises and the vapour pressure falls. With the compounds whose tests are summarised in table 1 and figure 1, those with vapour pressures exceeding 1 mm. Hg are toxic at relative saturations of less than 0.6, but with less volatile compounds the relative saturation apparently required increases, till with compounds of 0.3 mm. vapour pressure the figure is 1.0 and with compounds of 0.25 mm. or less vapour pressure the figure is in excess of unity.

It is considered that these findings are an artifact, and that the values so obtained have been falsified by the factor of adsorption of much of the added vapour on the walls of the fumigating vessel. As a result, the vapour dose available to the insects suspended therein is considerably less than that assumed on the basis of the amount of material added to the container. The assumed or nominal concentrations of these low vapour pressure compounds at the median lethal level will thus often prove to exceed the known saturation concentration figure.

The factor of adsorption, which is higher the less volatile the compound (Ledoux, 1945), becomes particularly important for the low vapour pressure materials studied here. The ability of glass vessels to remove fumigant vapours from the enclosed air is well-known as a source of error in mammalian toxicity experiments (Wachtel 1941). All the compounds in question, with boiling point >200° C., proved lethal to *Tribolium* adults in concentrations at or slightly below saturation, when administered in a constant-flow apparatus; the mortality after 5 hours' exposure was usually 100 per cent and never below 50 per cent, provided that the insects were not separated from the source of the vapour (fritted disc bubblers) by too great an extent of glass tubing or cage material. On the other hand, a glass vessel that had been filled with the vapour issuing from the bubblers, and then tested with *Tribolium* adults, did not engender more than 15 per cent mortality, presumably due to loss of vapour by adsorption on the glass walls.

This factor of adsorption is therefore responsible at least in part for the steepness of the slope of the toxicity-boiling point relationship in the case of compounds of low volatility. It is also probable that it is a factor (although a smaller one) in the steepness of the slope given by the results obtained on more volatile fumigants by the other workers mentioned, all of whom have used closed glass containers, which were of considerably smaller size than the vessels used in the present study. Adsorption may be regarded therefore as a factor causing the increase of the relative saturation required to kill (C_t/C_s or toxic thermodynamic activity) with increase in boiling point. It has been considered by Ferguson & Pirie that this increase, in the case of insect fumigants, is implicit in the decrease of toxicity with ascent of a homologous series, such as has been established for bactericides, haemolytic agents, mammalian narcotics, and inhibitors of development in Arbacia eggs (Ferguson 1939). However, in the light of the findings reported, much of this increase may be an illusion in the case of insect fumigants due to adsorption on the container. And instead of the cut-off of toxicity in the ascent of a homologous series occurring at a thermodynamic activity (relative saturation) of 1.0, it may continue at apparent thermodynamic activities considerably in excess of unity, where the nominal vapour concentration simultaneously satisfies the adsorptive capacity of the container and maintains a true vapour concentration sufficient to kill the insects.

The relationships discussed above apply to fumigants whose action may be classed as physical. The more active chemical poisons show much lower toxic thermodynamic activities. With such compounds, including the commercial fumigants tested by Shepard *et al.*, the plots of toxic concentration against boiling point do not fall on the straight-line relationship; they would fall to the lower left of line B of figure 1. Fumigants classifiable as chemical poisons may occur also among low vapour pressure compounds. Due to the factor of adsorption, they show figures for toxic thermodynamic activity (C_t/C_s that are unusually high for chemical poisons. A number of such compounds are listed in table 2; they are readily recognizable as chemical poisons if their toxicities are plotted on figure 1, for they will fall well to the lower left of line B. Dichloroethyl ether and dichloroethyl sulphide, both β,β'-substituted compounds, are examples of lower vapour pressure compounds whose action may be classified as chemical.

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Piperonyl Formulations as Horse Fly Repellents

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During the past 4 years many of the new insecticides have been tested by the Oklahoma Agricultural Experiment Station to determine their value for the control of tabanids in this area. Of these, DDT, benzene hexachloride, chlordan and Toxaphene produce appreciable mortality for a day or two following spraying; but they provide little repellency. Only materials containing piperonyl butoxide or piperonyl cyclonene were significantly repellent when used in safe concentrations. During the 1948 fly season, four formulations containing these materials were tested on a small herd basis.

LOCATION.—The experiments were performed on the J. Nolan ranch approximately five miles north of McAlester on U. S. highway 69. An intermittent stream containing many permanent pools ran through the pastures used. Two farm ponds provided additional permanent water. The major portion of the pasture was open grassland, but occasional oak and persimmon thickets were present and the margins of the ponds and streams were heavily wooded. Adjoining the pasture area was an extensive oak-hickory forest.

PROCEDURE.—Gentle, purebred Hereford cattle were used exclusively. These animals allowed anyone to walk among them and count the flies without difficulty. Before spraying, a number was stenciled on each animal and the number of flies present was recorded at half-hour intervals over a period of 2 days. From these data the animals were grouped into five lots of five cattle each so that the collective attractiveness of each group was approximately equal. During the counting period the average fly population ranged from 7 to 29 per animal. Spraying was done with 3-gallon compressed air sprayers. Each animal received 1 liter of spray between 7:00 and 8:00 a.m. on the first day of each test. Animals in check group were unsprayed, but they ran with the sprayed animals. Other herds in the vicinity were counted at regular intervals and the number of flies on them compared with those on the check animals to determine if possible the effect of the sprayed animals on the fly population. Flies on sprayed and check animals were counted as often as possible. The number of counts per day varied with the weather and the grouping of the cattle. When the animals were widely scattered during grazing, counts were necessarily fewer than when the cattle were bunched. When the fly population on the sprayed animals approached 50 per cent of that on the checks, the animals were resprayed.

The materials used were supplied as emulsion concentrates. These were diluted at the rate of 1 part of concentrate in 14 parts of water and each animal received 1 liter of spray per application. The concentration of toxicants in each spray is shown in table 1.

Table 1.—Number of grams of toxicants per liter of spray.

FORMULATION	PIPERONYL BUTOXIDE	PIPERONYL CYCLONENE	PYRETHRINS A AND B	ROTENONE
143	6.67 gr.	—	0.67 gr.	—
232	5.33 gr.	—	0.13 gr.	—
235	—	5.33 gr.	0.13 gr.	—
334	5.33 gr.	—	0.13 gr.	0.67 gr.

RESULTS.—The tests with the four spray materials were repeated four times during August and once in September. The first replication was discontinued after the second day because a drenching rain shortly after the sprays were applied apparently washed off much of the spray. The test during September (Replication D) was included but probably has little significance due to the small number of flies present. During that month, the number of flies on the checks averaged less than 3 per count per animal; whereas, during other periods, the average count was 16 to 42 per animal.

The details of these experiments are shown in Fig. 1. The data are shown as a per cent of the flies on

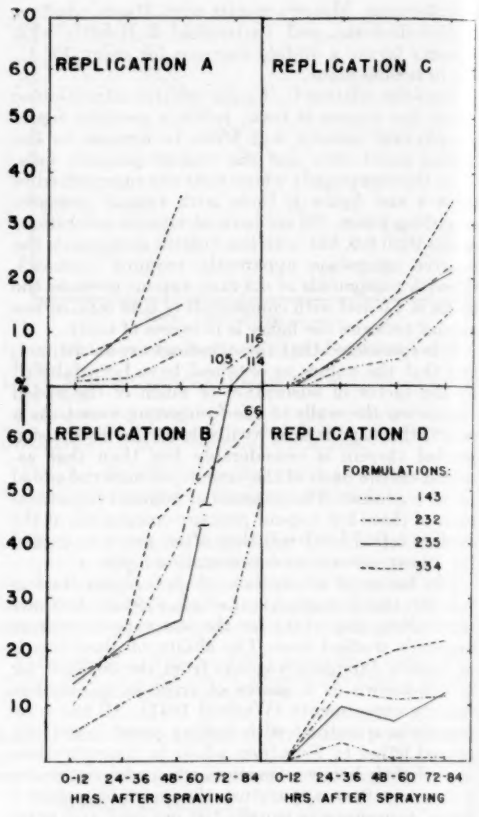

FIG. 1.—Relative infestation of flies on test animals (check 100%).

test animals compared with those on the sprayed animals to express more clearly the relationshlp that would be obscured by the varying populations due to factors other than the spray.

Spray formulation 143 consistently provided better control than the other materials. Formulation 232 and 334 gave similar results, indicating that the addition of 0.67 gr. of rotenone per liter added very little to the control of tabanids. Piperonyl cyclonene was less effective than piperonyl butoxide in these tests.

Tabanus abactor Philip and *Tabanus sulcifrons* Macq. comprised over 80 per cent of the flies present. *Tabanus vittiger* Stone and *T. atratus* Fab. were common during the first 3 weeks of August. Small numbers of *T. mularis* Stone, *T. venustus* O. S., *T. americanus* Drury, *T. giganteus* Degeer and several *Chrysops* were seen.

DISCUSSION.—A satisfactory control for tabanids is greatly needed in many parts of this country. To be of real value for use with range animals, such a material should last at least a week to reduce the losses resulting from handling animals, it should be relatively non toxic, and also should be inexpensive. No material available at present meets these requirements but piperonyl butoxide comes closest. It is relatively non-toxic and provides fair protection for 2 to 3 days. It may have a place in the control of flies

(*Continued on page 404*)

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Need for Standard Formulations

Investigators on the control of agricultural insects seldom prepare their own formulations. More often they secure for trial commercial products manufactured by reputable chemical firms. As a result, although the percentage of a given toxicant may not vary greatly from year to year, the investigator has little assurance that the mixture he uses in consecutive trials was compounded with the identical auxiliary substances and with identical formulating equipment. Undoubtedly, this fact accounts in a large measure for the variable results obtained from year to year, and between various investigators working on the control of the same insect.

Long ago entomologists ought to have acknowledged this lack of uniformity and taken steps to correct it. It is fully realized that most Experiment Stations and federal laboratories do not have facilities to prepare their own formulations; and if the did, it would be difficult to duplicate exactly formulations used by other entomologists. The logical alternative—*set up standards of commonly used toxicants and make provision for entomologists to secure these standard materials from the same source.*

Unless this service were undertaken by an insecticide firm, it would be too large an undertaking for any one state or federal research organization to prepare sufficient quantities to meet the demands of our entomologists. Doubtless, it would be a big responsibility to organize and to put such a plan into execution, but the increased value of research data which would accrue by using identical materials would be well worth the effort.

This does not imply that state and federal entomologists should not evaluate commercially available products. It is felt that such responsibility lies within the scope of duties of public service entomologists engaged in research. However, the failures and successes of commercial products on trial could be better interpreted if entomologists had full specifications on these products. An accurate evaluation of a given toxicant can only be made when identical auxiliary materials are employed and applied under similar conditions.

Recently it has been a common practice to compare the efficacy of the newer insecticides with DDT. The information we have on these DDT formulations is often vague. We do know that they contain a certain percentage of the active material, that they are solutions, emulsion concentrates, wettable powders, or agricultural dusts; beyond these generalities we often know little.

Could we not agree on a standard 5 per cent DDT dust, for example, or a 50 per cent wettable powder which would serve as a yardstick to compare the newer insecticides year after year and to compare the value of DDT year after year? We would at least know more what is meant when we say that "formulation B is twice as good as DDT." We would not only have a clear concept of the type of formulation; in addition, we would have an exacting set of specifications. The research worker would be more certain that this formulation would behave similarly in another year if applied under similar conditions. DDT is cited as an example. Similar standards could be developed for other more common insecticides.

Rumors are floating about that "DDT doesn't kill like it used to." If this is true, is it the formulation, or are insects developing an immunity? Standard insecticides used in consecutive years would also assist immeasurably in solving these problems.

Such a plan is not new in research on household insecticides. The Official Test Insecticide of the National Association of

Insecticide and Disinfectant Manufacturers for evaluating household fly sprays, in spite of its limitations, has served as an invaluable tool for testing fly sprays for many years.

Disinfectants are similarly evaluated by means of a standard for rating their bacteria-killing power according to the numerical value of the "Phenol Coefficient," a number which represents the bactericidal value of the candidate disinfectant as compared to a standard. Numerous instances of this type of standardization in other fields could be cited.

It is well known that all auxiliary substances such as wetting and emulsifying agents, stickers, diluents, etc., do not allow the toxicant to always behave similarly. In fact, there is "no such animal" as an "inert ingredient" in the strictest sense.

The fact that a dust possesses 5 per cent by weight of DDT with a melting point of approximately 89° F. gives the user little assurance that this particular formulation can be compared in killing power with any agricultural dust containing 5 per cent technical DDT. In final analysis, the performance of the insecticide is more important to the user than the percentage of toxicant; and the performance of a given insecticide is dependent largely upon the choice of diluents or upon other auxiliary substances.

The facts herein presented are not new. The difficulties encountered in developing uniform standards and putting the plan into execution are not unsurmountable. It is suggested that the President of the American Association of Economic Entomologists appoint a committee to determine the feasibility of inaugurating such a program.

H S. TELFORD

SCIENTIFIC NOTES

(*Continued from page 402*)

on dairy cattle or in protecting animals against flies that are spreading anaplasmosis or anthrax, but its cost will reduce its usefulness for all but such special needs.

SUMMARY.—1. Four piperonyl formulations were tested against horseflies, using the small herd method.

2. Piperonyl butoxide and pyrethrins provided the best control.

3. The addition of rotenone to the piperonyl formulation added little to the control obtained.

4. *T. sulcifrons* and *T. abactor* were most commonly found, but at least nine other species of horseflies were seen.

PROFESSOR W. B. HERMS DIES SUDDENLY

Word has been received from Dr. E. O. Essig that Professor Millima B. Herms suffered a heart attack and died suddenly on May 9, presumably in Berkeley, California.